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THE PERCEPTUAL REDINTEGRATION OF FREQUENT AND INFREQUENT WORDS[1]

P. L. NEWBIGGING
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ALTHOUGH IT HAS BEEN SHOWN in a number of experiments (for example, Howes & Solomon, 1951; Solomon & Postman, 1952) that frequency of occurrence in the written language is a major determinant of recognition thresholds for words, the way in which frequency has its effect on the threshold has not as yet been fully analysed. Two quite different interpretations are currently held. Rosenzweig and Postman (1958), for example, suggest that a word increases in visibility as a function of its frequency of use. Goldiamond and Hawkins (1958), on the other hand, conclude that frequency does not affect visibility but does affect response bias. They argue that the lower threshold of frequent as compared with infrequent words is attributable to the higher probability of such words being given as responses in the recognition threshold experiment.

Goldiamond and Hawkins (1958) used a very special procedure to obtain logarithmic recognition frequency curves which were open only to interpretation in terms of response bias and not in terms of perception. In their experiment differential response biases for nonsense syllables were built up in subjects in a training task which required them to pronounce the syllables different numbers of times. This task was followed by a pseudo-perceptual task in which the subject was instructed that on any given trial one of the syllables from the training task would be presented for a brief interval and he was to guess which syllable it was. Instead of one of the syllables being presented, however, Rorschach Plate 1 was flashed for .02 seconds. The frequency with which the subjects guessed the different syllables correlated perfectly with the frequency with which the syllables had been presented in the training task.

As has been pointed out (Newbigging, 1960) the training task in the Goldiamond and Hawkins experiment constitutes a very important procedural difference from the usual recognition threshold experiment and limits the generality of their results. In the training task the subject becomes familiar in different degrees with a limited number of syllables (twenty-three) and is subsequently instructed in the recognition task that the syllables presented will be taken from the familiar list. With the

[1]The research for this paper was supported in part by the Defence Research Board of Canada under Grant no. 9401–13. My thanks are due to Miss Janet Hay for experimental assistance.

range of responses limited in this way, differential response strength attributable to experimentally controlled frequency may fully account for the results.

In word recognition experiments when response alternatives are not restricted by a preceding training task, that is by providing the subject with a list of the words that are to be presented for recognition or other similar means, it is estimated that subjects respond in terms of a set of alternatives approximating 30,000 words (Miller, Heise, & Lichten, 1951). In such cases it would appear obvious that the sensory information the subject receives by the tachistoscopic presentation of the word, as well as differential response biases, operates as a determinant of the threshold. The problem then becomes one of assessing the relative role of each of these determinants in accounting for the lower thresholds of frequent as compared with infrequent words.

Solomon and Postman (1952) propose an explanation of the effect of word frequency on the threshold which incorporates the role of both sensory information and response bias. They suggest that when a word is presented at a short duration only a few letters or a fragment of the word is seen by the subject. This fragment may be common to a number of words and if the subject is instructed to guess the word presented he will respond with the word of greatest frequency of occurrence (that is, response strength) which incorporates the seen fragment. If the stimulus is a low-frequency word, however, guesses to small seen fragments will be high-frequency words and therefore wrong. An infrequent word will have to be exposed for a duration sufficiently long that a large fragment common only to one or few infrequent words is seen. Essentially, then, it is proposed that the subject redintegrates the stimulus word from a seen fragment, the size of the fragment required varying as a function of the frequency of the stimulus word. In this way the lower thresholds of frequent as compared with infrequent words are accounted for.

The experiment to be reported was designed to test the following predictions derived from this interpretation: (1) If frequent words have a greater response strength than infrequent words then (*a*) they should occur more often among pre-recognition responses, and (*b*) frequent response words should have a shorter latency than infrequent response words. (2) Responses immediately preceding recognition of infrequent stimulus words should incorporate more of the letters of the word than responses immediately preceding recognition of frequent stimulus words.

Method

Subjects

Ss were 9 male and 9 female volunteers from a local teachers' college. They ranged in age from 18 to 23 (to nearest birthday) with a mean age of 20.5.

Apparatus

The list of 24 words given in Table I was used. It will be noted that for each frequency there are words of four different lengths: one word is ten or more letters in length, one eight letters, one six, and one four.

TABLE I

STIMULUS WORDS

*1/3.6 million**	*1/1.8 million*	*1/million*
histrionic	apoplectic	fractional
fructify	optician	leniency
noster	iambic	belfry
tong	bosh	tome
25/million	***50/million***	***100/million***
depression	opportunity	understand
ceremony	economic	building
sketch	motion	either
sole	fold	gave

*Frequency of occurrence according to the Thorndike-Lorge general count.

Each word was typed in élite capital letters on a white card. The words were presented for recognition in a Gerbrand's tachistoscope. A Hunter KlocKounter was connected in the circuit with the timer of the tachistoscope so that both were started simultaneously. S stopped the KlocKounter by releasing a telegraph key.

Procedure

S was instructed as follows: "I am going to present some words to you one at a time. If you look in the eye-piece of the box you will see two lines. The words I shall show you will appear directly between the lines. Each word will be presented for a very short period of time and you may not be able to tell what the word is at first. However, after each presentation I want you to make a guess as to what the word was. Remember, even if you do not recognize the word I still want you to tell me what you think it was. Each word will be presented to you several times until you have correctly recognized it. I will inform you when you are correct and then I will show you another word. I shall say 'ready' before each word is flashed. When I say 'ready' I want you to hold down the key and watch between the two lines. After the word is flashed and you are ready to say what you think the word was, release the key. Remember, hold the key down when I say 'ready' and release it when you are ready to say the word you think was flashed."

It will be noted from these instructions that S was required to respond with a word to every presentation. The presentation of the experimental list was preceded by three practice words (McMASTER, TEACHER, HAMILTON) to familiarize S with the task. The experimental list was then presented in a different random order for each S. For every word the first exposure was for 20 millisec. and successive exposures were increased by 10 millisec. until correct recognition occurred. *E* recorded the response word and the response time for each exposure.

RESULTS

Thresholds

The threshold data are presented as a function of frequency of occurrence of the stimulus word in Figure 1, and a summary of an analysis

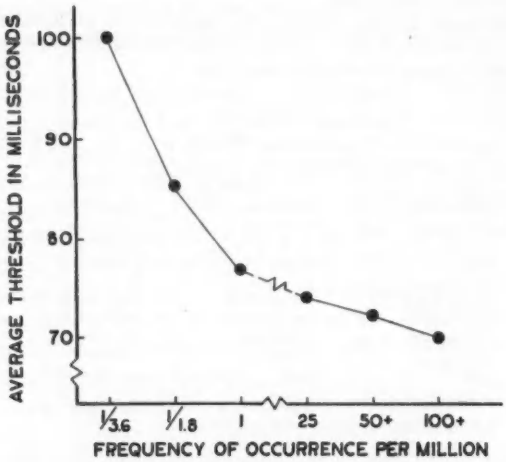

FIGURE 1. Average threshold in milliseconds plotted as a function of the frequency of occurrence in the written language of the stimulus words.

of variance is given in Table II. The significant main effect of frequency was of course expected, as was that for length. An examination of the data shows that the significant interaction between frequency and length reflects a tendency for long words to have higher thresholds only when

TABLE II

SUMMARY OF ANALYSIS OF VARIANCE OF THRESHOLD DATA

Source	df	MS	F	p
Subjects	17	26.42		
Frequency	5	88.10	21.08	$<.01$
Length	3	22.18	5.67	$<.01$
Subjects × frequency	85	4.18	—	
Subjects × length	51	3.91	—	
Frequency × length	15	20.77	4.01	$<.01$
Subjects × frequency × length	255	5.18	—	
TOTAL	431	—	—	

very infrequent words are considered. These findings are of interest only in that they confirm those reported by McGinnies, Comer, and Lacey (1952).

For simplicity in subsequent analyses, the data for the three groups of infrequent words (1/3.6 million, 1/1.8 million, and 1/million) have been

pooled as have those for the three groups of frequent words (25/million, 50/million, and 100/million).

Response Similarity

Two indices of the similarity between the subject's response word and the stimulus word were computed. The first, termed letter similarity, was obtained by counting the number of letters in the response word which were the same as the letters in the stimulus word. To this total was added one point for each correct pair of letters which were adjacent and in the right order. Thus, the response word MASTER to the stimulus word NOSTER would be scored 7, or 63.6 per cent similar, since the maximum number of points in the example is 11. While this index is imperfect, it nevertheless permits desired comparisons between response words given to frequent and infrequent stimulus words.

The data for letter similarity of response words to frequent and infrequent stimulus words for four critical responses is plotted as a function of exposure duration in Figure 2. The plot had to be restricted to four

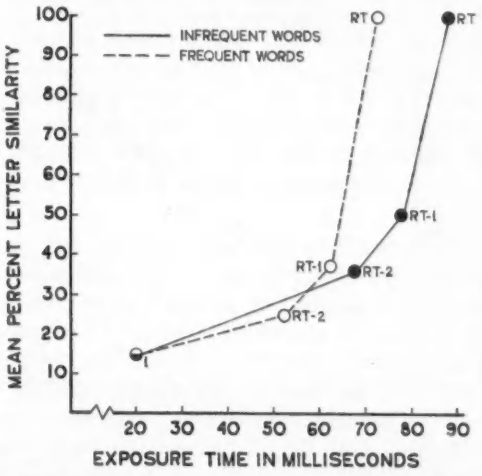

FIGURE 2. Mean per cent letter similarity of four critical response words plotted as a function of the exposure time in milliseconds.

points on each curve in order to include every subject in each point. It will be noted that letter similarity for the response immediately preceding correct recognition (RT—1) and the response before that one (RT—2) is greater for infrequent than for frequent words. The Wilcoxon matched-

pairs signed-ranks test was used to test the significance of these differences with the following results: RT—1 ($T = 35$, $p < .025$), RT—2 ($T = 22$, $p < .01$). Letter similarity for RT—1 for frequent words is not significantly different from RT—2 for infrequent words nor are the exposure times for these responses significantly different. This suggests that the number of letters correctly recognized (and thus the similarity index) in a briefly presented word is a simple function of the length of the presentation.

The second index of response similarity is similarity of length. To obtain this the difference in the number of letters between the response word and the stimulus word was obtained, disregarding whether the response word was longer or shorter. Thus response words of 6 and 10 would be scored as 75 per cent similar in length to a stimulus word of 8 letters. The data for similarity of length of response words to frequent and infrequent stimulus words for four critical responses are plotted as a function of exposure duration in Figure 3. The two curves in this figure

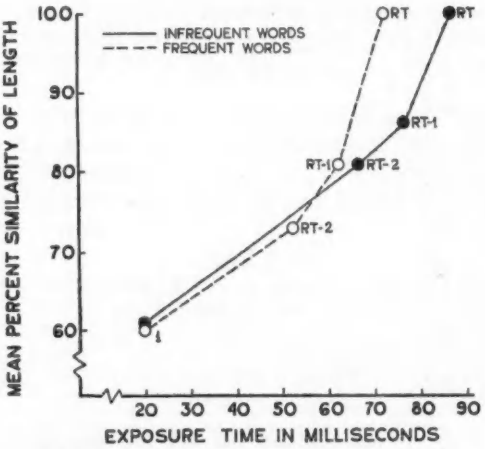

FIGURE 3. Mean per cent similarity of length of four critical response words plotted as a function of the exposure time in milliseconds.

are essentially similar in shape to those for letter similarity. Tested by the Wilcoxon matched-pairs signed-ranks test both RT—1 and RT—2 for frequent and infrequent words are significantly different: ($T = 12.5$, $p < .005$) and ($T = 1$, $p < .005$), respectively. As was the case with letter similarity, similarity of length for RT—1 for frequent words is not significantly different from RT—2 for infrequent words, nor are the

exposure times for these responses significantly different. Both indices of response similarity then yield essentially the same result.

Frequency of Words Given as Pre-recognition Responses to Frequent and Infrequent Stimulus Words

The mean Thorndike-Lorge frequency of two pre-recognition responses to frequent and infrequent stimulus words are given in Table III. For

TABLE III

MEAN FREQUENCY OF PRE-RECOGNITION RESPONSES TO FREQUENT AND INFREQUENT STIMULUS WORDS

	Frequent stimulus words	Infrequent stimulus words	
RT−1	45.83 (62.08)*	29.07 (77.25)	$p < .01$
RT−2	53.96 (52.08)	40.00 (67.25)	$p < .01$
	$p = .025$**	$p < .01$	

*The numbers in brackets are the mean exposure durations in milliseconds associated with each response.

**p values refer to the mean frequencies and were obtained by Wilcoxon's matched-pairs signed-ranks test.

ease of comparison the mean exposure duration in milliseconds associated with each response is also included in the table. It is exident from the table that for both responses RT—1 and RT—2 response words are of relatively high frequency, though less frequent response words are given to infrequent stimulus words. It is also evident that the mean frequency of response words correlates closely with exposure duration.

Response Time

The response time reported is the time elapsing from the onset of the stimulus to the beginning of the subject's response. These data for the four critical responses to frequent and infrequent stimulus words are plotted as a function of exposure duration in Figure 4. It is evident from Figure 4 that response time is directly related to exposure time for all responses up to correct recognition (RT), for which response time drops precipitously. Comparing response times for responses to frequent and infrequent stimulus words, those for the latter are obviously much longer. To determine if the differences were significant the Wilcoxon matched-pairs signed-ranks test was used with the following results: RT ($T = 5$, $p < .005$), RT—1 ($T = 35$, $p < .025$), RT—2 ($T = 22$, $p < .01$). Response times for the first response are not significantly different.

DISCUSSION

The results of this experiment appear entirely in accord with the proposed interpretation of the effect of frequency in determining the recognition threshold. This interpretation includes the role of both sensory

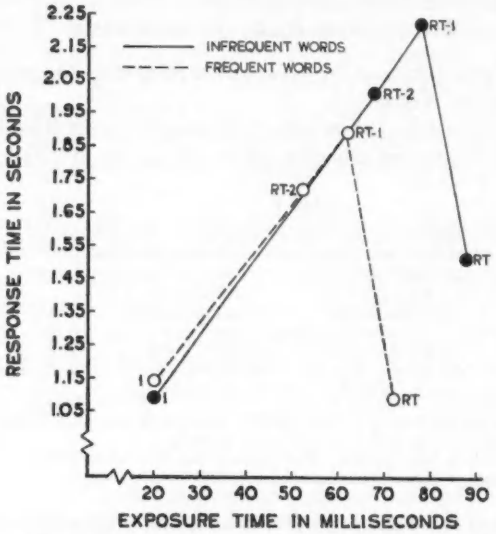

FIGURE 4. Response time in seconds of four critical response words plotted as a function of the exposure time in milliseconds.

information and response strength and defines recognition as the redintegration of the stimulus word from a seen fragment.

First, it is clear that responses immediately preceding correct recognition of infrequent stimulus words show greater similarity to the stimulus word by both indices of similarity employed (letter similarity and similarity of length) than do the comparable responses to frequent stimulus words. One difficulty to be faced in the interpretation of these data is that it is unknown how much of the stimulus word the subject sees on that exposure which is followed by the correct verbal response. It could be, though it seems unlikely, that he sees the whole word and not just a fragment. It can only be inferred from the fact that his response word immediately preceding correct recognition of infrequent stimulus words is more similar to the stimulus word than is the case for a frequent stimulus word, that on the next exposure he simply sees a sufficiently larger fragment to correctly redintegrate the word. If this inference is accepted, then it may be concluded that a larger fragment of an infrequent word is required for correct redintegration than for a frequent word.

Second, it was demonstrated that responses immediately preceding correct recognition of both infrequent and frequent stimulus words tend to be words of relatively high frequency of occurrence in the written language. An incidental finding of some interest is that the pre-recognition response words to infrequent words tend to be significantly less frequent in occurrence than pre-recognition response words to frequent stimulus words. This finding may be interpreted in the following way. If, as seems to be the case, the subject sees an increasingly large fragment of the stimulus word on successive exposures and incorporates these into his response, then infrequent stimulus words should elicit infrequent response words, just prior to correct recognition, because the subject's response approximates the stimulus word itself.

Third, and finally, it was shown that frequent response words do have a significantly shorter latency. This is true both for the pre-recognition responses considered and for the correct response which defines recognition. Up to correct recognition response latency appears to be a simple function of exposure duration. This is consistent with the interpretation proposed in that it will be recalled that the frequency of the response words decreases as exposure duration increases. The precipitous drop in response latency at the threshold indicates that once a sufficiently large fragment is recognized, redintegration of the stimulus word occurs quickly.

Summary

Twenty-four words differing in length and frequency of occurrence were exposed for recognition to 18 Ss. (1) The usual frequency-threshold relationship was obtained. (2) An analysis of pre-recognition responses showed that pre-recognition responses to infrequent stimulus words were more similar to the stimulus word than was the case for frequent stimulus words. (3) Pre-recognition responses to infrequent stimulus words were less frequent in occurrence in the language than were pre-recognition responses to frequent words. (4) Response latency was longer when the response was an infrequent word. These results are taken as evidence that both sensory information and response bias act as determinants of word-recognition thresholds.

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(*First received September 30, 1960*)

THE PERCEPTUAL REDINTEGRATION OF WORDS WHICH DIFFER IN CONNOTATIVE MEANING[1]

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THERE HAS BEEN CONSIDERABLE EXPERIMENTAL INTEREST in connotative meaning as a determinant of recognition threshold for words. In different experiments, connotative meaning has been varied in terms of the emotional significance of words (e.g. McGinnies, 1949), word value (e.g. Solomon & Howes, 1951; Postman & Schneider, 1951; Johnson, Thomson, & Frincke, 1960), and "goodness" or "badness" as defined by rating on the good-bad scale of the Semantic Differential (Johnson, Thomson, & Frincke, 1960). Some authors have attempted to explain the effect of connotative meaning in terms of frequency. Solomon and Howes (1951), for example, argue that values operate to produce idiosyncratic variations in word frequency. A subject high in aesthetic value, the argument goes, is likely to read material containing words relevant to his dominant value area and therefore these words have a higher frequency for him than for the general population. The predictably lower recognition threshold for these words as compared with words of equal population frequency and relevant to other value areas is explained in terms of this idiosyncratic frequency and not in terms of connotative meaning. In a recent experiment, however, Johnson, Thomson, and Frincke (1960) have shown that when frequency is held constant, connotative meaning acts as a determinant of the threshold.

The question remains: how does connotative meaning have its effect on the threshold? The terms "perceptual sensitivity" and "perceptual defence" have been variously used as descriptive labels for the observed effects. Johnson, Thomson, and Frincke (1960) favour the following explanation: "It may be that the differential reinforcement of various stimuli causes those stimuli (as well as those responses) that have most frequently led to reinforcement in the past to be more readily observable or available in the present." They go on to say that because of the reinforcement history of a word "the stimulus qualities of rewarding or reinforcing words would be such that less information is needed before the word is correctly recognized than would be the case for words which were presented with equal frequency but were not equally reinforcing.

[1]The research for this paper was supported in part by the Defence Research Board of Canada under Grant no. 9401–13. My thanks are due to Miss Janet Hay for experimental assistance.

Something that might be called perceptual sensitivity might then be said to exist." (p. 341)

The essential point of this argument would appear to be that because of past reinforcement a smaller fragment of a reinforcing word (defined as rated toward the "good" end of the good-bad scale on the Semantic Differential) would elicit the correct response than would be required for a non-reinforcing or negatively reinforcing word (defined as rated toward the "bad" end of the good-bad scale on the Semantic Differential).

In a recent experiment, Newbigging (1961) showed that words occurring frequently in the written language according to the Thorndike-Lorge count are redintegrated from smaller recognized fragments, as judged from the similarity of the response preceding correct recognition of the stimulus word, than is the case for infrequently occurring stimulus words. The purpose of the present experiment is to apply the method of analysis used in that experiment to pre-recognition responses to words varying in connotative meaning, specifically, varying in ratings on the good-bad scale of the Semantic Differential. If the interpretation of the effect of connotative meaning proposed by Johnson, Thomson, and Frincke is correct, that is, that more information is required for the recognition of "bad" as compared with "good" words, pre-recognition responses to "bad" words should be more similar to the stimulus word than is true for "good" words. This would indicate that with "bad" words, a larger fragment of the word, or cue, is necessary for the correct redintegration of the word.

Method

Subjects

Ss were 9 male and 9 female volunteers from a local teachers' college. They ranged in age from 19 to 25 (to nearest birthday) with a mean age of 20.6.

Apparatus

The list of eighteen words given in Table I was used. The words were selected from the list published by Jenkins, Russell, and Suci (1958) so as to constitute three groups of six according to good-bad rating: one group rated at the "good" end of the scale, one group rated near the middle of the scale, and a third group rated at the "bad" end of the scale. So far as possible the three lists were equated according to length and frequency of occurrence.

Each word was typed in élite capital letters on a plain white card. The words were presented for recognition in a Gerbrand's tachistoscope. A Hunter KlocKounter was connected in the circuit with the timer of the tachistoscope so that both were started simultaneously. S stopped the KlocKounter by releasing a telegraph key.

Procedure

S was instructed as follows: "I am going to present some words to you one at a time. If you look in the eye-piece of the box you will see two lines. The words I

TABLE I

STIMULUS WORDS

	Number of letters	Frequency	Rating on good-bad scale
Graceful	8	19*	1.90**
Harmonious	10	6	1.83
Lovable	7	3	1.77
Patriot	7	17	1.90
Radiant	7	13	1.87
Symphony	8	6	1.87
	7.83	10.67	1.86
Boulder	7	5	4.17
Frosty	6	8	3.73
Politician	10	25	3.90
Socialism	9	4	4.57
Somber	6	7	3.63
Spanking	8	9	3.67
	7.67	9.67	3.94
Crooked	7	18	5.93
Discomfort	10	6	6.10
Mosquito	8	8	6.17
Putrid	6	1	6.37
Sickness	8	25	6.30
Stagnant	8	4	6.27
	7.83	10.33	6.19

*Frequency of occurrence according to the Thorndike-Lorge general count.
**Ratings reported by Jenkins, Russell, and Suci (1958).

shall show you will appear directly between the lines. Each word will be presented for a very short period of time and you may not be able to tell what the word is at first. However, after each presentation I want you to make a guess as to what the word was. Remember, even if you do not recognize the word I still want you to tell me what you think it was. Each word will be presented to you several times until you have correctly recognized it. I will inform you when you are correct and then I will show you another word. I shall say 'ready' before each word is flashed. When I say 'ready' I want you to hold down the key and watch between the two lines. After the word is flashed and you are ready to say what you think the word was, release the key. Remember, hold the key down when I say 'ready' and release it when you are ready to say the word you think was flashed."

It will be noted from these instructions that S was required to respond with a word to every presentation. The presentation of the experimental list was preceded by three practice words (McMASTER, TEACHER, HAMILTON) to familiarize *S* with the task. The experimental list was then presented in a different random order for each *S*. For every word the first exposure was for 20 millisec. and successive exposures were increased by 10 millisec. until correct recognition occurred. *E* recorded the response word and the response time for each exposure.

Results

Thresholds

The threshold data are presented as a function of the good-bad scale ratings of the stimulus words in Figure 1. A Friedman two-way analysis

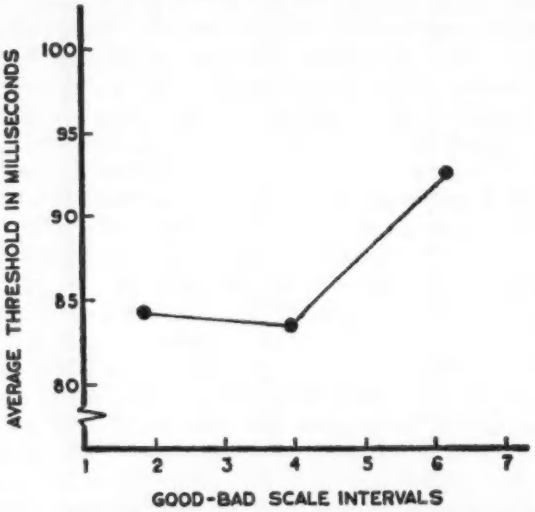

Figure 1. Average threshold in milliseconds plotted as a function of the rating on a good-bad scale of the stimulus words.

of variance by ranks was performed on the threshold data yielding a $\chi^2_r = 8.08$ ($p < .02$). Subsequent comparisons of pairs of lists using the Wilcoxon matched-pairs signed-ranks test showed the thresholds of "bad" words to be significantly higher than either "good" or "neutral" words, but thresholds, of these latter two lists are not significantly different from each other. (For "good" and "neutral" words $T = 65.5$ (N.S.); for "good" and "bad" words $T = 28.5$ ($p < .01$); and for "neutral" and "bad" words $T = 16.5$ ($p < .005$).) Since these lists did not differ significantly, the data for "good" and "neutral" words were pooled to simplify subsequent analyses.

Response Similarity

Two indices of the similarity between the subject's response word and the stimulus word were computed. The first, termed letter similarity, was obtained by counting up the number of letters in the response word that were the same as those in the stimulus word and adding to this total

one point for each correct pair of letters which were adjacent and in the right order. Thus, the response word SYMPATHY given to the stimulus word SYMPHONY would be scored 9, or 60 per cent similar, since the maximum number of points in the example is 15. While the index is imperfect, it nevertheless permits desired comparisons between response words given to the different lists of stimulus words.

The data for letter similarity of "good" and "neutral" and for "bad" stimulus words for four critical responses are plotted as a function of exposure time in Figure 2. The plot had to be restricted to four points

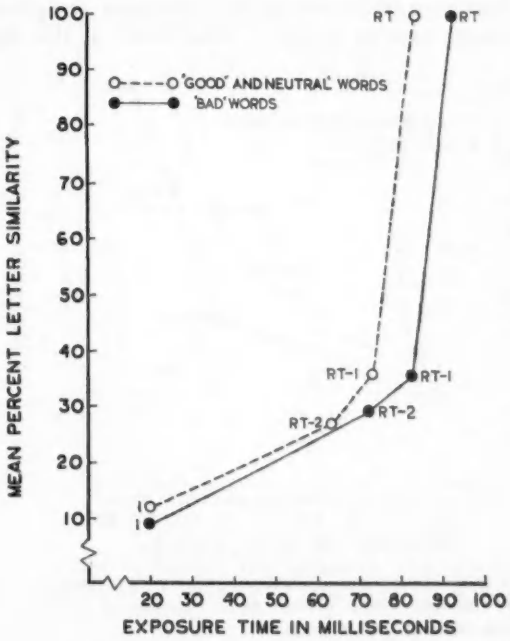

FIGURE 2. Mean per cent letter similarity of four critical response words plotted as a function of the exposure time in milliseconds.

on each curve in order to include every subject in each point. It will be noted from the figure that letter similarity for the response immediately preceding correct recognition (RT—1) and the response before that one (RT—2) does not appear to be different for "good" and "neutral" as compared with "bad" words. The slight differences observed were tested

for significance using the Wilcoxon matched-pairs signed-ranks test with the following results: RT—1 ($T = 96$, N.S.), RT—2 ($T = 46$, N.S.). This lack of significant differences in letter similarity is of particular interest because the RT—1 and the RT—2 responses for "good" and "neutral" words are significantly different from the corresponding responses for "bad" words in terms of exposure time. The conclusion to be drawn is that "bad" words must be exposed for a significantly longer time than "good" and "neutral" words for the same-sized fragment (as measured by letter similarity) to be recognized.

The data for similarity of length of response words to "good" and "neutral" and "bad" words for four critical responses are plotted as a function of exposure time in Figure 3. The curves in this figure are

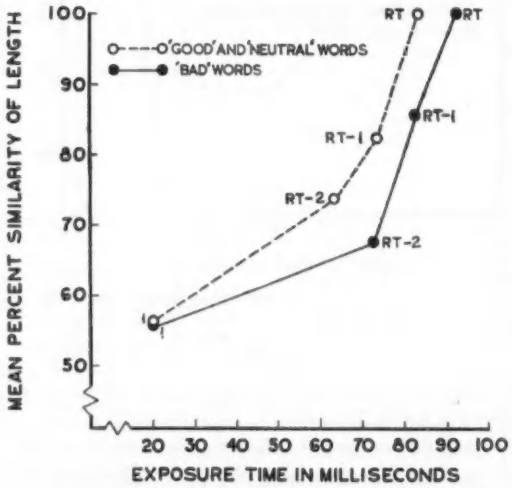

FIGURE 3. Mean per cent similarity of length of four critical response words plotted as a function of the exposure time in milliseconds.

essentially similar in shape to those for letter similarity. Tested by the Wilcoxon matched-pairs signed-ranks test neither RT—1 nor RT—2 for "good" and "neutral" words are significantly different in length from the corresponding responses for "bad" words ($T = 39$, N.S., and $T = 43.5$, N.S., respectively). While these responses do not differ significantly in terms of similarity of length, they do differ significantly in terms of exposure time. This is the same result as was obtained for letter similarity.

Response Time

The response time reported is the time elapsing from the onset of the stimulus to the beginning of the subject's response. These data for four critical responses to "good" and "neutral" and "bad" stimulus words are plotted as a function of exposure time in Figure 4. It is evident from

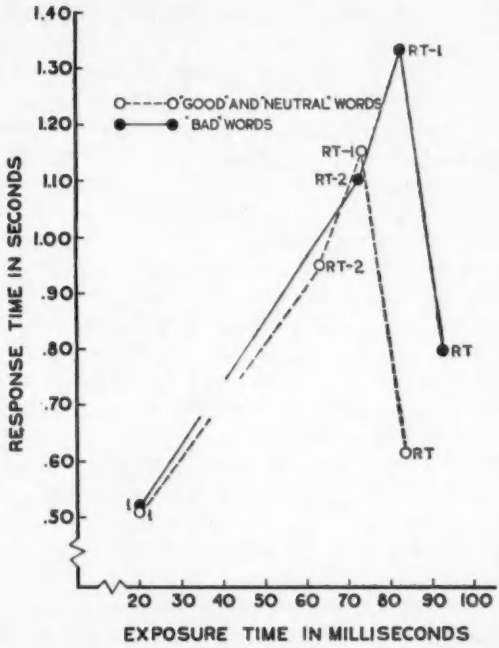

FIGURE 4. Response time in seconds of four critical response words plotted as a function of the exposure time in milliseconds.

Figure 4 that response time is directly related to exposure time for all responses up to correct recognition (RT) for which response, response time drops precipitously. Comparing response times for "good" and "neutral" with those for "bad" words, times for the latter are obviously much longer. To determine if the differences are significant the Wilcoxon matched-pairs signed-ranks test was used with the following results: RT ($T = 7$, $p < .01$); RT—1 ($T = 38.5$, $p < .025$); RT—2 ($T = 67$, N.S.).

Discussion

The results of this experiment confirm the finding reported by Johnson, Thomson, and Frincke (1960) that words rated towards the "good" end of the good-bad scale of the Semantic Differential have a lower recognition threshold than do words rated towards the "bad" end.[2] They do not, however, support these authors' interpretation of how connotative meaning has its effect on the threshold. According to their interpretation, less information (that is, a smaller fragment or cue) would be required for the correct redintegration of "good" as compared with "bad" stimulus words. Of critical importance to this interpretation is the finding that, according to both indices of similarity employed (letter similarity and similarity of length), there is no significant difference in similarity between the response words given immediately prior (RT—1) to the recognition of "good" and "neutral" as compared with "bad" stimulus words. These words, then, are redintegrated from the same size fragment. It would appear that connotative meaning affects the threshold in a different manner from word frequency since in a previous paper (Newbigging, 1961) it was shown that a larger fragment of an infrequent stimulus word was required for correct redintegration than was the case for a frequent stimulus word. Since it was also shown that a longer exposure time was required for recognition of the larger fragment, the higher threshold of infrequent words was entirely explained.

Two findings in the present experiment would seem to require the postulation of an inhibitory or perceptual defence mechanism. These are, first, that a significantly longer exposure time is required for the recognition of the same size fragment (as measured by the two indices of response similarity) of "bad" as compared with "good" and "neutral" stimulus words, and, second, that the response time for the response preceding the recognition of "bad" words (that is, RT–1) is significantly longer than that for "good" words and "neutral" words. Consistent with this is the additional finding that the correct verbal response at recognition (RT) has a longer latency for "bad" as compared with "good" and "neutral" words. It would appear necessary, then, to conclude that in some way the recognition of fragments of "bad" words is inhibited as is the verbal response incorporating the recognized fragment.

It is possible only to speculate about how this perceptual defence or inhibitory process operates and the following is offered in that vein.

[2]Of some interest is the failure to find a significant difference in the thresholds of "good" as compared with "neutral" words. On the basis of a mechanism of perceptual sensitivity it would have been predicted that "good" words would have a lower threshold. The slight difference observed is opposite to that prediction.

Essentially what is proposed is a two-process theory. First, it is postulated that experienced stimulus words leave a trace whose strength is a simple function of the number of times the word has been experienced. The strength of the trace may be inferred from the size of the word fragment required to elicit the correct verbal response. The effect of word frequency on the recognition threshold may be explained entirely in terms of the trace hypothesis if this line of reasoning is accepted, since it has been shown (Newbigging, 1961) that a larger fragment of infrequent as compared with frequent stimulus words is required to elicit the correct verbal response. Where frequency is controlled, however, as in the present experiment, and connotative meaning is the variable, the trace hypothesis alone will not account for the results obtained since the word traces in all connotative meaning classes will be of the same strength. It is proposed that a second process that operates in an inhibitory manner on the trace is involved. Presumably certain letter combinations involved in "bad" words become conditioned to some emotional response that has an inhibitory effect. McGinnies' (1949) finding of a greater PGR response prior to the recognition of "taboo" as compared with non-taboo words suggests such a process. The finding in the present experiment, that it requires a significantly longer exposure time for the recognition of the same size fragment of a "bad" as compared with a "neutral" or "good" word suggests that this inhibitory process operates on perception as well as on the motor response, as is suggested by the significantly longer response times for "bad" words even prior to their correct recognition.

Summary

Eighteen words varying in connotative meaning as defined by rating on the good-bad scale of the Semantic Differential were exposed for recognition in a Gerbrand's tachistoscope to each of 18 Ss. The main findings were: (1) that "bad" words had a significantly higher threshold than "good" and "neutral" words; (2) that "bad" and "good" and "neutral' words were correctly redintegrated from the same size fragment, as measured by two indexes of similarity of pre-recognition responses to the stimulus word, but that a significantly longer exposure time was required for the recognition of the fragment of the "bad" words; (3) response times for the response preceding recognition and for the correct response was significantly longer for "bad" as compared with "good" and "neutral" stimulus words.

These results are interpreted in terms of a perceptual defence mechanism.

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SHORT-TERM RETENTION AND MEANINGFULNESS[1]

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RETENTION HAS BEEN FOUND to decrease markedly within seconds after one presentation of a consonant syllable (Peterson & Peterson, 1959). Repetition of the item by the subject immediately after presentation was found to increase recall. Repetition was also accompanied by an increase in the sequential dependency of letters on the immediately preceding letter in the syllable. Repetition of the syllable was shown to constitute a serial learning task in which successive letters were in turn response and then stimulus.

Since frequency is related to meaningfulness (Underwood & Schulz, 1960, ch. 5) it was predicted that the short-term retention of items would vary as their meaningfulness. It was further predicted that sequential dependencies between letters at recall would vary with meaningfulness of items.

EXPERIMENT I

Subjects

Eighteen students from introductory psychology courses at Indiana University served as subjects. Participation in experiments was a requirement of the course.

Retention Materials

A low association value set of 16 items was originally selected from Glaze's 0 per cent nonsense syllables (1928), but was later found in Archer's more recent norms for trigrams (1960) to have a mean value of 13.1 per cent. Sixteen nonsense items in another set from Glaze's 100 per cent list had a mean Archer value of 84.9 per cent.

A set of 16 three-letter words was selected from Thorndike and Lorge's (1944) list of words occurring more than 100 times per million words of written English, and had a mean Archer value of 99.2 per cent.

Apparatus

The items were presented on a memory drum set in a 3 by 4 ft. black screen. A sliding shutter permitted exposure of eight columns of items without change of tape. The drum was set to turn every 1.1 sec. during periods of activation. The drum motor was controlled by two decade interval timers.

Procedure

A sequence started with the exposure of a three-letter item for 1.1 sec., while S spelled the item aloud. The drum then turned to a three-digit number and S began counting backward by three or four from the number. Six sec. after the removal

[1]This research was facilitated by research grant G 12917 from the National Science Foundation.

of the letters from the aperture a bell rang and the drum turned to a blank space. S stopped counting and attempted to recall the item by spelling it aloud. Twelve sec. after the bell rang the drum turned to another blank space and then to a new item. S was given six practice presentations in which he was corrected for procedural errors.

The experiment proper consisted of 48 presentations in which S counted backward by three during half of the session and by four during the remainder. Instructions for change in the counting task were given during a short break after the twenty-fourth presentation. Each of the three types of item occurred equally often within each block of six presentations. Order of presentation within a block of six was randomized.

Results and Discussion

Marked differences in recall directly related to association value are apparent in Table I. A treatment by subject analysis of variance of the number of items correctly recalled resulted in an F of 28.4 for the treatment conditions. With 2 and 34 degrees of freedom this F is significant at the .001 level.

TABLE I

Recall in Experiment I

Response class	Proportion of items recalled		Sequential letter probabilities		Proportion of first letters recalled	
	$\bar{X}$	$\sigma_{\bar{X}}$	$\bar{X}$	$\sigma_{\bar{X}}$	$\bar{X}$	$\sigma_{\bar{X}}$
Low N.S.	.58	.05	.83	.02	.77	.04
High N.S.	.64	.03	.92	.02	.73	.03
Words	.85	.03	.98	.01	.86	.03

The serial dependencies within the items were analysed by calculating the conditional probabilities that a letter was correctly recalled given that the preceding letter was correct. Table I shows that the sequential letter probabilities were also directly related to association value. All comparisons of these dependent probabilities among the three conditions were significantly different at the .01 level by two-tailed sign test. It is clear that in the case of words, if the first letter was correctly recalled, it was very likely that the other letters would follow correctly.

Analysis of the mean frequencies of recall of the first letters showed no significant differences. An analysis of variance resulted in an F of less than one.

A check was made on the subjects' perception of the items by noting errors in reading the items from the drum. Three subjects made a total of six errors, two errors occurring in each of the experimental conditions. The positive relationship between association value and recall cannot be attributed to differences in perception of the items.

The predictions are confirmed by the data. The results of this experiment, together with the earlier study, are consistent with the hypothesis that frequency is a basic variable producing differences in association-value and letter-sequence habits as secondary phenomena (Underwood & Schulz, p. 44). It seems plausible that highly integrated units should be recalled better than poorly integrated items. Another possibility is that the associations evoked by items might facilitate recall either by stimulating correct responses or by providing a means for recognition of errors. Since mediating associations would require time to occur, the latency of correct recalls should vary with the association value of the item recalled. A second experiment was designed to compare latencies among sets of trigrams selected from the extremes of Archer's scale and tested at either a 1- or 6-sec. retention interval.

Experiment II

Sixteen students without previous experience in short-term retention experiments were drawn from the source previously described. Twenty-four nonsense syllables below 11 per cent on Archer's scale formed one set of items and 24 words of 100 per cent Archer value the other. A Standard Electric timer was wired into the apparatus previously described. It was automatically activated when the bell rang to signal recall and was stopped by *E* depressing a key after a third letter was spoken by *S*. The time from ringing of the bell to start of the next presentation was increased to 18 sec.

Recall intervals of 1 and 6 sec. were combined with the two types of items in a factorial design in which all comparisons were within subjects. The four experimental conditions were each represented in random order within each block of four presentations. In all other respects Experiment II followed the procedures of Experiment I.

Results and Discussion

It is seen in Table II that differences in recall related to association value appeared only at the 6-second interval. An analysis of variance was contra-indicated by the gross differences in variability between the 1- and 6-second conditions. A t test of the difference between words and nonsense syllables in number of items recalled at 6 seconds resulted in a t of

TABLE II

Recall in Experiment II

Response class	Proportion of items recalled				Latency of items recalled			
	1 sec.		6 sec.		1 sec.		6 sec.	
	$\bar{X}$	$\sigma_{\bar{X}}$	$\bar{X}$	$\sigma_{\bar{X}}$	$\bar{X}$	$\sigma_{\bar{X}}$	$\bar{X}$	$\sigma_{\bar{X}}$
Low N.S.	.96	.02	.38	.05	2.05	.13	2.67	.18
Words	.98	.01	.82	.03	1.84	.10	2.63	.16

9.0, which with 15 degrees of freedom is significant at the .001 level. The corresponding difference at 1 second is not significant. The amount of forgetting after 1 second is not appreciable for either condition. Differences in number of items recalled between 1 and 6 seconds are significant at the .01 level by two-tailed sign tests for both types of items.

The latencies were analysed by computing the mean latency of correct items in each of the four conditions for each individual. When examination of the distributions of these mean latencies showed no marked departures from normality nor any appreciable heterogeneity of variance, an analysis of variance was applied. The association value F was not significant ($F = 4.19$, df $= 1$ & 15). The hypothesis that mediating associations facilitate recall is not supported by the data. The rôle of mediating responses in learning may be limited to associative aspects and not be of any consequence in response recall.

A significant difference in latency was found for recall interval ($F = 24.8$, df $= 1$ & 15). However, interpretation of this finding is obscured by the fact that the intervening task was reading a number in the case of the 1-second interval, and counting backward in the 6-second interval. A further experiment was designed in which latency at short intervals was investigated.

Experiment III

Subjects were instructed to begin counting backward immediately at the start of the recall interval by speaking a number three units less than the number appearing in the drum. Thus, the task for the 1-sec. condition was the same as for the other conditions of the experiment. Recall intervals of 1, 2, 3, or 6 sec. were each tested 21 times with every S. The items were trigrams of Archer association value below 16 per cent. The interval from signal for recall to beginning of the next test was 15 sec. Other details were the same as in Experiment II.

Results

Table III shows that recall at the 1-second interval did not differ appreciably from recall at that interval in Experiment II. Frequency of correct recalls after 1 second was slightly lower in the present experiment, but on the other hand the mean latency of correct recalls was somewhat

TABLE III

Recall in Experiment III

Response measure	Recall interval (sec.)			
	1	2	3	6
Proportion correct	.92	.88	.79	.51
Mean latency (sec.)	1.89	2.06	2.23	2.73

shorter. Latencies of correct recalls increased gradually with lengthening of the recall interval. Mean latencies of correct recalls at the 1-second recall interval were shorter than those at the 6-second interval for all 12 subjects. A Friedman two-way analysis of variance by ranks results in a χ^2_r of 26.7 which is significant at the .001 level (df = 3).

Examination of the frequency data and the latency data of individual subjects does not reveal any abrupt changes in the characteristics of recall over the first 6 seconds after presentation. Thus there is no evidence here to suggest that immediately after presentation retention is maintained by a mechanism different from that effective at 6-second intervals.

Summary

Recall of individual trigrams after 6 sec. was found to vary with meaningfulness as measured by association value. At recall sequential dependencies between letters within the items were found to vary with association value. Frequency of occurrence in recall of initial letters did not vary with association value. It was concluded that letter-sequence habits may underlie differences in response recall related to meaningfulness. Mean latencies of correct responses at a 6-sec. recall interval were not different between sets of trigrams from the two extremes of Archer's scale, even though gross differences in recall were found. It was therefore considered unlikely that mediating responses had any significant role in response recall. Increases in latency and decreases in frequency of correct responses were found to be gradual over recall intervals of 1, 2, 3, and 6 sec. for low association value trigrams.

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SERIAL-TRIGRAM LEARNING AS A FUNCTION OF DIFFERENTIAL MEANINGFULNESS AND SEX OF SUBJECTS AND EXPERIMENTERS

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IN A RECENT MONOGRAPH, Archer (1960) reported the re-evaluation of meaningfulness of all possible consonant-vowel-consonant (CVC) trigrams. It was found that some trigrams appeared more meaningful to women and others appeared more meaningful to men.

The purpose of the present research was to examine a logical deduction from the previous study: since, in general, speed of learning is a function of meaningfulness, then the trigrams which were more meaningful to women should be learned more rapidly by women than those which were judged more meaningful to men; and the opposite should obtain for men.

Since the judged meaningfulness of trigrams is probably affected by many subtle variables, it was thought that one potential variable of interest for the present study might be the sex of the experimenter. Accordingly, serial lists of trigrams, selected for differences in meaningfulness for the two sexes, were learned by men and women subjects and presented by either a male or a female experimenter.

PROCEDURE

Subjects

Twelve men and twelve women students from introductory psychology courses served individually for four days. None of the *Ss* had had previous experience with a verbal learning experiment.

Experimenters

Six men and six women *Ss* served under the direction of the female *E* (JAC) and the responsibility for the other 12 *Ss* was divided between the two male *Es* (EJA and CPT). Except for this restriction, the *Ss* were randomly assigned to the *Es*.

Apparatus and Task

Each *S* learned three lists of 12 trigrams by the serial-anticipation method. An additional (13th) trigram was not anticipated but served only as a starting cue. Each trigram was presented for 2 sec. with a 2-sec. blank period between the last and the first. The stimuli were presented by a 16 mm. Dunning Animatic strip-film projector onto a translucent screen mounted in the wall of *S*'s cubicle. The *S* sat in a darkened, sound-absorbent cubicle measuring 4 × 4 × 8 ft. His responses were monitored by *E* with ear-phones.

[1]This paper was prepared while the first-named author was a National Science Foundation Senior Post-doctoral Fellow at the Applied Psychology Research Unit, Cambridge, England.

The Ss were instructed to spell each syllable just before it appeared, and to learn the list as quickly as possible.[2]

Following a general explanation of the task, S learned the first list to the criterion of one perfect anticipatory trial. He was then urged to avoid rehearsing the list and to return the following day. On the second day (24 hrs. after attaining the criterion) S was instructed to recall as many of the items as possible on the first relearning trial and to continue relearning to the same criterion of one perfect trial. After relearning, S was given a 5-min. rest and then presented with a new list of 13 trigrams. This procedure was repeated until S had learned and relearned all three lists.

Lists

The three lists of trigrams were constructed so as to meet the following conditions: (*a*) equal and minimal intra-list similarity, and (*b*) nearly equal means and variances of association values. The three lists differed in terms of their differential meaningfulness to the sexes. A "neutral" list contained 13 trigrams for each of which the difference in association value for the two sexes was less than 5 per cent. A "female" list contained 13 trigrams, each of which had been judged to be significantly more meaningful to women. The "male" list contained 13 trigrams each of which had been judged to be significantly more meaningful to men. The lists and their association values are shown in Table I.

TABLE I

THE THREE LISTS OF TRIGRAMS WHICH WERE USED WITH THE ASSOCIATION VALUES FOR THE TWO SEXES INDICATED

Female			Male			Neutral		
	Assoc. value			Assoc. value			Assoc. value	
Trigram	Women	Men	Trigram	Women	Men	Trigram	Women	Men
KYS	57	34	DEG	33	56	JOV	62	64
TAW	68	50	JIZ	28	44	PUM	63	59
NOZ	88	73	FOC	44	66	ZIN	44	49
DEK	76	56	MEX	58	75	QAK	52	56
WIX	51	36	QIP	42	56	SOG	80	79
MOQ	46	24	GAT	73	86	BEJ	24	24
KAG	49	32	BUW	15	27	CYQ	31	30
PEZ	58	44	SYF	33	49	GID	66	61
FOH	50	35	HAJ	11	25	WUX	17	17
SAJ	40	22	ZEK	44	59	HOC	86	91
QUT	49	30	WAP	67	81	FAZ	56	54
MYC	60	36	NIG	73	88	VIP	86	90
DUV	70	48	VEH	20	37	TUF	89	90
MEAN	59	40		42	58		58	59

[2]This study was started twice. On the first attempt we requested the Ss to *pronounce* the trigrams in any way they wished, rather than spell them. Such a procedure would have more nearly approximated the conditions under which the trigrams were evaluated for meaningfulness. We avoided specifying any particular pronunciation since that would have biased S's perception of the meaningfulness of the trigram.

The procedure was abandoned however, because the Ss were so inconsistent from trial to trial that *E* could not be certain of the responses. The data from this first start were discarded, of course.

Design

A split-plot design was used with sex of S and sex of E orthogonal. Each of the four cells contained two 3 × 3 latin squares. The lists were assigned to the latin letters. The same square was used eight times and it was therefore possible to analyse for differences among the three sequences of lists. The Ss were randomly assigned to a sequence.

Results

Trials to Criterion

The primary response variable was the number of trials required to achieve the criterion of one perfect anticipatory trial. A summary of the analysis of variance of these data is shown in Table II.

TABLE II

Summary of Analysis of Variance of Number of Trials to Attain the Criterion

Source	df	Mean square	*F*
Sex of *E*	1	3200.000	3.871
Sex of *S*	1	346.722	
Sequence	2	4432.181	5.362*
Sex of *E* × seq.	2	1561.625	1.889
Sex of *S* × seq.	2	1271.181	1.538
Sex of *E* × sex of *S*	1	4867.556	5.889*
Sex of *S* × sex of *E* × seq.	2	1715.514	2.075
Ss/Groups	12	826.611	9.665***
Days	2	1637.347	19.144***
Lists	2	311.014	3.636*
Days × sex of *E*	2	117.542	1.374
Days × sex of *S*	2	140.264	1.640
Days × sex of *E* × sex of *S*	2	135.014	1.579
Lists × sex of *S*	2	3.431	
Lists × sex of *E*	2	133.782	1.564
Lists × sex of *S* × sex of *E*	2	60.597	
Square uniqueness	2	35.097	
Sq. uni. × sex of *E*	2	22.542	
Sq. uni. × sex of *S*	2	56.017	
Sq. uni. × sex of *E* × sex of *S*	2	109.344	1.278
Residual	24	85.528	
TOTAL	71		

*$p < .05$
***$p < .001$

Table III is in the form which would demonstrate the primary hypothesis of this study, that is, there would be an interaction between the sex of the subject and the "sex" of the list. As may be seen the hypothesis was not supported, that is, women did not learn the list of trigrams, previously judged to be more meaningful to women, significantly faster than the list which had been judged to be more meaningful to men; in

TABLE III

MEAN NUMBER OF TRIALS TO ACHIEVE THE CRITERION AS A FUNCTION OF THE SEX OF THE SUBJECTS AND THE LISTS

		"Sex" of lists			
		Female	Male	Neutral	Over-all average
Sex of subjects	Female	42.6	35.8	37.2	38.6
	Male	47.0	40.8	40.8	42.8
	Over-all average	44.8	38.2	39.0	40.6

fact, the opposite occurred. The performance of the men was consistent with the prediction, however.

The over-all averages indicate that the three lists probably were not of equal difficulty. For no obvious reason the "female" list seems to be more difficult to learn than the other two; the "male" and "neutral" lists were very nearly equally difficult.

Although the men required approximately two more trials, on the average, to achieve the criterion, the difference between the sexes was not significant.

The finding of greatest interest is shown in Table IV. This table shows the mean number of trials to criterion as a function of the sex of subject and sex of experimenter. While neither of the main effects is significant, this interaction is.

TABLE IV

MEAN NUMBER OF TRIALS TO CRITERION AS A FUNCTION OF THE SEX OF THE SUBJECTS AND THE EXPERIMENTERS

		Sex of subjects	
		Male	Female
Sex of experimenters	Female	41.3	53.4
	Male	44.4	23.6

As may be seen from Table II, there were three other significant sources of variation in the trials-to-criterion data. (*a*) The three sequences differed as a function of the order in which the unequally difficult lists appeared. The easiest sequence occurred when the easiest list (see Table III) came first and the most difficult list came last. The most difficult sequence occurred when the list of intermediate difficulty came first and the easiest list was last. Apparently, allowing the subject to practise on easy lists before taking on more difficult ones has an advantage. (*b*) Individual differences accounted for a significant part of variation. (*c*) There was a significant learning-to-learn effect; the mean number of

trials to criterion for each of the three days was 49.3, 39.8, and 32.8, respectively.

Recall and Relearning

Unlike the learning data, the data for recall and relearning showed little effect of the independent variables.

In the analysis of the recall data only individual differences and practice effects were significant. The latter finding is consistent with those previously found (Underwood, 1957); retention degraded as a function of the number of prior lists learned. The mean number of correct responses on recall for each of the three consecutive days was 8.2, 4.5, and 3.8, respectively ($F = 33.390$, 2 and 24 df, $p < .001$).

As would be expected from the recall data, in general, the subjects required more trials to relearn the previous day's list to criterion as a function of the number of prior lists learned. This was the only source of variation which was significant in the analysis of the relearning data. The mean number of trials to relearn for each of the three consecutive days was 5.9, 8.6, and 8.3, respectively ($F = 4.012$, 2 and 24 df, $p < .05$).

Discussion

It appears as if the performance of the men was uninfluenced by the sex of the experimenters, but the performance of the women was drastically affected by the sex of the experimenters. When women served for the female experimenter they required over twice as many trials to achieve the criterion as when comparable subjects served for male experimenters. The most reasonable explanation is in terms of the motivation of the subjects under the two conditions. Before hypothesizing as to the nature of this motivation, however, it would be well to observe this sex of $E \times$ sex of S interaction in other circumstances. Conceivably, it is a major source of subject variation which has heretofore been designated as error variance or it may even be the basis for some unexpected findings in previous learning studies.

It is conceivable that the primary hypothesis would have been supported if the subjects had been required to pronounce the trigrams (see footnote 2). However, since most subjects appear to pronounce trigrams to themselves, and sometimes overtly, even though instructed to spell the response, it seems unlikely that this procedural difference alone could account for the lack of support of the prediction. Other explanations seem more likely; the differential meaningfulness, while statistically significant for each item alone, may not have been enough to have a significant effect on learning. In addition, while the trigrams were individually different for the sexes, the differential meaningfulness may have been diminished

when the items were placed in a list. Sampling differences always remain a possibility, but these were minimized since the subjects in the present study came from the same population used in the trigram re-evaluation study.

At least two other comments might be in order. The first concerns the negative findings. If familiarity is independent of meaningfulness, then it might be possible that those trigrams which were more meaningful to one sex were in fact more familiar, or at least equally familiar, to the other sex. In this way familiarity might counteract the effect of meaningfulness. Lindley (1960) offers some evidence for this position. However, the results he obtained may have been due to the unreliability of the Glaze-Krueger materials (see Archer, 1961). The writers would prefer to regard familiarity and meaningfulness as correlated, so that an increase in familiarity would lead to an enhancement in meaningfulness.

The other comment concerns the unexpected sex of $E \times$ sex of S interaction. Perhaps, it might be argued, it was not the sex of the experimenters which was important, but rather the results were due to personality differences of the experimenters. This may be so, but then the problem still remains of the interaction of some unknown personality characteristic of the experimenters with some equally unknown personality characteristic of the subjects. Again, it should be noted that the main effect of sex (or personality) of the experimenters was insignificant.

Summary

The present study tested the primary hypothesis that women should learn more rapidly the list of trigrams judged more meaningful by women than the list judged more meaningful by men, and the opposite should obtain for men. The results did not confirm this hypothesis. The significant learning-to-learn effect and the cumulative interference effect upon recall was in accordance with previous findings. Finally, a major methodological finding was a significant interaction between sex of S and sex of *E*; the performance of male Ss was unaffected by the sex of the *E*, but the female Ss serving for the female *E* required more than twice as many trials to learn as when comparable female Ss served for male *E*s.

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TACTUAL-KINESTHETIC JUDGMENT: EFFECT OF BKD[1,2]

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THE RESULTS OF A STUDY of the asymmetry of the perception of size between the right and left hands, reported by McPherson and Renfrew (1953), showed that "objects of equal size held simultaneously in each hand tend to be judged to be unequal, and that, in the majority of subjects, the object held in the dominant hand is perceived to be the smaller." (p. 66) Wertheimer (1954) states that his results "confirm McPherson and Renfrew's findings, at least with regard to right-handed subjects." (p. 546)

More recently, Churchill (1959) reported that right-handed subjects showed an underestimation bias when interpolating on a diameter scale under tactual-kinesthetic conditions. These results were confirmed in a later study (Churchill, 1960) and, in addition, it was shown that an underestimation bias of the same order of magnitude obtained when the reference diameters were sensed visually and the comparison diameters were judged through the tactual-kinesthetic sense. The procedure followed in these two studies allowed subjects to contact the comparison stimuli with either hand, or each in turn, that is, use of the hands was not controlled when making judgments.

The results reported by McPherson and Renfrew, and by Wertheimer, would seem to imply that the underestimation bias reported by Churchill might well have been the result of the more frequent use of the dominant hand by right-handed subjects.

In view of this implication, an experiment was conducted to establish the effective contribution of bilateral kinesthetic difference to the underestimation bias obtained from the tactual-kinesthetic judgments. The (Ti) condition of the 1960 study, that is, tactual-kinesthetic judgments between visually presented references, was repeated using the right and left hands alternately. The apparatus was as described by Churchill (1959) and the procedure and subjects as described by Churchill (1960).

Errors were classified as overestimations (positive errors) or underestimations (negative errors). Seventy-one per cent of the judgments were in error, of which 16.0 per cent were overestimations and 55.0 per cent were underestimations. The 16.0 per cent overestimations were com-

[1]Defence Research Medical Laboratories Report No. 164-13, DRML Project No. 164, PCC No. D77-94-20-27, H.R. No. 208.

[2]Wertheimer's term: Bilateral Kinesthetic Difference.

prised of 7.7 per cent with the right hand and 8.3 per cent with the left hand. The 55.0 per cent underestimations were comprised of 26.9 per cent with the right hand and 28.1 per cent with the left hand. The over-all underestimation bias was, therefore, 19.2 per cent with the right hand and 19.8 per cent with the left hand.

The distributions of errors, that is, overestimations, underestimations, and total errors, were compared between the two hands, as were the response distributions. Chi square analysis showed no significant differences between the two hands. The constant error curves for the right and left hands were essentially the same as that shown for both hands in the 1960 study under the same experimental conditions. The mean constant error for all right-hand judgments was —0.79 scale unit and, for the left-hand judgments, —0.75 scale unit.

It is apparent from the results of this study that there was no appreciable difference between judgments made with the right and left hands, and that, therefore, BKD was not operative under the conditions tested. It is to be noted, however, that the studies in which BKD has been shown to obtain have been conducted under conditions of direct comparisons between the two hands.

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SOME EFFECTS OF TEMPORAL-LOBE DAMAGE ON AUDITORY PERCEPTION[1]

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IN MAN, damage restricted to the auditory receiving area of one or both sides of the brain is relatively rare. Unilateral lesions of the temporal lobes, however, with or without involvement of Heschl's gyrus, are fairly common, and have provided us with some useful data in understanding auditory perception.

Most studies have been concerned with the differential effect of such lesions on the efficiency of the two ears. Data on acuity typically reveal either no loss (Jerger, 1960) or a slight loss of high frequencies in the ear opposite the lesion (Sinha, 1959). Studies on sound localization suggest that the relative input from the two ears may be altered by temporal-lobe damage, making sound localization defective, at least in the contralateral auditory field (Jerger, 1960; Longo, Forster, & Auth, 1957; Penfield & Evans, 1934). In general, however, impairment in the contralateral ear as measured by standard audiometric tests has been insignificant, and it is only recently that methods have been employed which yield reliable changes. Bocca, Calearo, Cassinari, and Migliavacca (1955) found that recognition of words distorted by a low-pass filter was significantly impaired on the side contralateral to a temporal-lobe tumour, whether the tumour was in the right or the left temporal lobe. Other methods of distortion, such as accelerated speech, produced the same effect. Words normally spoken were not so affected. A similar finding has been reported by Sinha (1959) in patients with atrophic lesions of the temporal lobes. Recognition of words normally spoken revealed no difference between ears, whereas words presented with white noise were less often recognized in the ear contralateral to the lesion. Sinha reported that there was no such effect in a control group of subjects with lesions in other parts of the brain. Recently Jerger and Mier (1960) also found that temporal lobectomy which included Heschl's gyrus resulted in impaired recognition of words on the contralateral ear. It thus appears that, although each ear sends fibres to the auditory

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[2]Now at the Montreal Neurological Institute.

cortex of both sides, the crossed connections are more effective than the uncrossed.

Temporal-lobe damage may also have its effect on the perception of specific types of auditory stimuli. Thus Milner (1958, 1961) has found that right temporal lobectomy (not including Heschl's gyrus) impairs performance on the Seashore tests of musical ability, particularly the tests of tonal quality and of tonal pattern discrimination. The latter finding is in accord with studies of bilateral ablation in the cat (Diamond & Neff, 1957) and the monkey (Jerison & Neff, 1953; Stepien, Cordeau, & Rasmussen, 1960). On the other hand, patients with lesions of the left temporal lobe were inferior to others in the recall of stories orally presented, a finding in agreement with Meyer and Yates (1955) who also employed spoken material. Milner has emphasized that these deficits underline the difference in function between the two hemispheres in man, a difference related to verbal and non-verbal abilities.

There are, then, two separate aspects to the effects of unilateral temporal-lobe damage on auditory perception. One is the impairment in recognition of stimuli arriving at the contralateral ear. The other is an impairment specific to certain kinds of stimuli, an effect which in man appears to vary with the laterality of the lesion. The present study further investigates both these aspects by using verbal stimuli, and by simultaneously presenting different stimuli to the two ears.

Method

Subjects

The Ss of this study were 71 patients at the Montreal Neurological Institute whose chief presenting symptom was the occurrence of epileptic seizures. In the majority of patients with focal cortical seizures the abnormality was due to atrophic lesions dating from birth or infancy. There were a few cases of adult head injury. No patients are included who had tumours, diffuse damage, or epileptic foci of doubtful origin.

Data on age and I.Q. are given in Table I. The mean I.Q. of all groups is in the average range, and the two temporal-lobe groups are particularly well matched for both age and I.Q. The subjects are grouped according to locus of abnormality based on EEG, X-ray, and clinical findings. In 55 of the 71 cases, a unilateral brain operation was performed in an attempt to remove the epileptogenic tissue. Of the 16 patients

TABLE I

Mean Age and I.Q.

Group	*N*	Mean age	Mean I.Q. (pre)	Mean I.Q. (post)
Left temporal	33	30.0	109.5	103.6
Right temporal	18	33.7	109.4	104.4
Frontal	10	26.3	106.6	103.1
Subcortical	10	18.7	102.5	—

not operated on, 10 had seizures of subcortical origin, 5 had unilateral temporal foci, and 1 had a unilateral frontal focus. Since these 6 unoperated unilateral cases were otherwise comparable to those in which an operation was performed, they are included in the preoperative analyses. This fact, and occasional difficulties in testing schedule, resulted in some subjects being tested only once, that is, either before or after operation. Most patients, however, were tested both before and again two weeks after the operation.

The removal in operations of the temporal lobe (see Figure 1) typically included

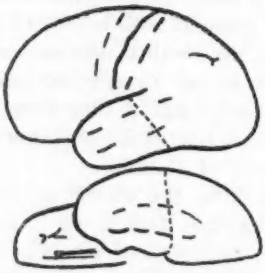

FIGURE 1. Typical temporal lobectomy, lateral and inferior surfaces. Dashed line marks excision.

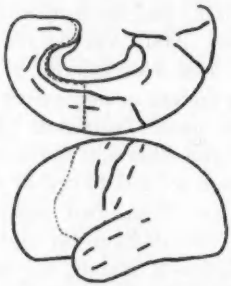

FIGURE 2. Typical frontal lobectomy in the dominant hemisphere, medial and lateral surfaces. Dashed line marks excision.

the superior, middle, and inferior temporal gyri, as well as the temporal pole, the uncus, amygdala, and varying portions of the hippocampus, hippocampal gyrus, and fusiform gyrus. Measurements of the removal cavity ranged from 5 cm. to 7 cm. along the Sylvian fissure, 5.5 cm. to 9 cm. along the base, in the right temporal lobe; 4 cm. to 7 cm. along the Sylvian fissure, 4 cm. to 7 cm. along the base, in the left temporal lobe. Complete removal of Heschl's gyrus was carried out in 6 cases (5 right-sided, 1 left-sided). These 6 cases are either omitted or treated separately in all analyses of postoperative data.

Frontal-lobe removals (see Figure 2) were more variable, but were usually radical lobectomies carried back to within a centimetre of the precentral gyrus on the medial and lateral surfaces, but sparing Broca's area in the dominant hemisphere. Thus the removal usually included area 8 as well as the cingulate and subcallosal gyri on the medial surface.

The subcortical group was so classified primarily on the basis of EEG activity (Penfield & Jasper, 1947). No operation was performed on these subjects and they are therefore not included in any postoperative analysis.

Procedure

A dual-channel tape recorder with stereophonic ear-phones was used for this test. Digits were presented in groups of six in such a way that half the digits came to the left ear, half to the right. After each group of six numbers the subject reported all the numbers he had heard, in any order he liked. There were three main conditions: (1) Two different numbers were presented simultaneously to the two ears,

one number of a pair to the left ear, the other to the right, in a manner first introduced by Broadbent (1956). Each group of six digits contained three such pairs, separated, in most groups, by intervals of half a second (simultaneous condition). (2) The six numbers were presented alternately to the two ears with a half-second interval between numbers. Half the groups started in the left ear, half in the right (alternating condition). (3) All six numbers were presented to one ear with a half-second interval between numbers. Half the groups were presented to the left ear, half to the right (digit span condition).

Conditions (1) and (2) combined consisted of 32 groups of six digits each, making a total possible score of 192, or 96 for each ear. Condition (3) was a control condition not included in this total score.

Results

Total Score

The combined total score for conditions (1) and (2) is presented for each group in Table II. A simple analysis of variance of the preoperative

TABLE II

Total Score

Group		*N*	Mean score	Range
Left temporal	pre	30	157.4	133–189
	post	21	149.9	126–186
Right temporal	pre	16	171.9	151–187
	post	11	171.5	134–187
Frontal	pre	9	165.3	139–186
	post	8	164.8	136–191
Subcortical	pre	10	161.8	134–186

scores yields an F ratio of 3.57 ($p < .02$). Subsequent t tests indicate that the only significant difference is between the left and right temporal-lobe groups ($p < .01$). The postoperative F ratio is 5.76 ($p < .01$), and the difference between the temporal-lobe groups is again significant ($p < .01$). The difference betwen frontal and left temporal groups approaches significance ($p < .06$). Since transient dysphasia often follows an excision in the dominant hemisphere, there was an occasional subject in the left temporal group who was dysphasic at the time of postoperative testing. Such subjects are excluded from the postoperative analyses in Tables II–IV, but not from the remaining analyses. Omitted from the postoperative analysis also were the six subjects who had Heschl's gyrus completely removed. For the remaining subjects, the average size of the removal is smaller on the left than on the right. Nevertheless, the performance of the left temporal group is inferior to that of the right, both before and after operation. Moreover, the excision causes a significant drop in performance for the left temporal group (Table III) but not for other groups.

This impairment, however, extended also to the digit span condition;

TABLE III

TOTAL SCORE FOR SUBJECTS TESTED BOTH BEFORE AND AFTER OPERATION

Group		*N*	Mean score	Difference
Left temporal	pre	19	156.9	7.2*
	post		149.7	
Right temporal	pre	10	173.8	1.4 N.S.
	post		172.4	
Frontal	pre	7	163.1	−2.6 N.S.
	post		165.7	

*$p < .02$

that is, patients with lesions of the left temporal lobe frequently were impaired in repeating six digits when they came in succession to only one ear. It was therefore decided to exclude from the next analysis those subjects who made more than one error in the digit span condition. The result is presented in Table IV. For these data, neither the preoperative

TABLE IV

TOTAL SCORE FOR SUBJECTS WITH GOOD DIGIT SPAN

Group		*N*	Mean score	Range
Left temporal	pre	20	164.5	142–189
	post	8	162.6	140–186
Right temporal	pre	15	172.9	151–187
	post	8	177.0	158–187
Frontal	pre	7	171.9	139–186
	post	6	172.7	136–191
Subcortical	pre	8	165.4	141–186

nor the postoperative *F* ratio is significant. The relative efficiency of the four groups is exactly the same as in Table II, however, and if we compare the data for the two temporal-lobe groups alone, we find that a simple *t* test yields a preoperative difference significant at the .04 level, and a postoperative difference significant at the .05 level. There is thus a tendency for the left temporal group to be impaired in the perception of digits arriving simultaneously or in quick succession to the two ears, even when the ability to repeat the same number of digits to one ear is unaffected.

Comparison of Ipsilateral and Contralateral Ears

Before operation, there was no difference between the scores for ipsilateral and contralateral ears. After operation, a simple comparison of ipsilateral and contralateral scores is not an adequate measure of the relative effect on the two ears. The reason for this is that, for all groups of

subjects tested, the preoperative score is higher for the right ear than for the left; that is, they are not equally efficient to begin with. A further complication is provided by the fact that, for the left temporal group, the excision often caused a decrease in score on both ears, though affecting them to different extents. For these reasons a comparison was made of the preoperative difference between ipsilateral and contralateral fields and the postoperative difference. This is shown in Table V. Again, subjects

TABLE V

EFFECT OF EXCISION ON CONTRALATERAL EAR

Group	*N*	Ipsilateral minus contralateral		Loss on contralateral
		Pre	Post	post minus pre
Temporal	30	−1.63	4.57	6.20*
Frontal	9	.56	−1.22	−1.78N.S.

*$p < .01$

with removal of Heschl's gyrus are excluded from the temporal-lobe group.

It is clear that temporal lobectomy results in a significant loss on the contralateral ear, whereas frontal lobectomy has no such effect.[3] The difference between the groups is significant ($p < .03$). The data for six subjects in whom the excision included Heschl's gyrus are presented in Table VI. It is apparent that the loss on the contralateral ear is accen-

TABLE VI

EFFECT OF EXCISION INCLUDING HESCHL'S GYRUS (6 SUBJECTS)

Ipsilateral minus contralateral		Loss on contralateral
Pre	Post	post minus pre
1.33	17.5	16.2*

*$p < .05$

tuated by an excision which includes this area. The difference between the loss for this group and the loss for the temporal-lobe group in Table V is not significant, however, due probably to the small *N*.

When the total loss on the contralateral ear (Table V) was broken down into separate scores for simultaneous and alternating conditions (Table VII), an interesting finding appeared. The loss on the contralateral ear is significant only under the simultaneous condition. The *t* ratio for the difference in the alternating condition is 1.27.

[3]The total score for the right temporal group does not change because the decrease on the contralateral ear is matched by the increase on the ipsilateral ear.

TABLE VII

COMPARISON OF TWO CONDITIONS (TEMPORAL-LOBE GROUP)

Condition	Loss on contralateral ear
Total score	6.20*
Simultaneous	5.63*
Alternating	.57 N.S.

*$p < .01$

DISCUSSION

The Left Temporal Lobe and the Perception of Spoken Material

The fact that patients with lesions of the left temporal lobe have poorer digit spans than those with lesions of the right confirms the suggestion of Meyer (1957) and Milner (1958) that these patients have striking deficits in the auditory appreciation of verbal material. That this difficulty with the immediate reproduction of spoken material is not a general attention deficit is indicated by the efficient performance of this group on other tests of attention, such as a letter-ordering task and a modification of the Knox Cube test (Kimura, 1960). Particularly interesting is the tendency for those patients who have good digit spans, indicating that they can perceive and reproduce digits correctly, to perform poorly under conditions in which different material is presented to the two ears. The left temporal group, in contrast to its poor performance on this verbal auditory task, achieves good scores postoperatively on certain non-verbal auditory tests cited earlier (Milner, 1961), tests on which the right temporal group is impaired postoperatively. It seems likely, therefore, that the left temporal lobe is specialized for the recognition of verbal material, at least in the auditory modality, and that it is particularly important in the analysis of verbal material coming from more than one source.

The Effect of Temporal-Lobe Removal on Contralateral Ear

It is clear that temporal-lobe excision, whether right-sided or left, impairs the perception of digits arriving at the contralateral ear, whereas frontal-lobe excision has no such effect. These results suggest that both temporal lobes take part in the elaboration of activity at the auditory receiving area of the same side. The impairment produced by the temporal-lobe operation, however, occurred only under conditions of simultaneous presentation of digits to the two ears. The successive or alternating condition in the present study somewhat resembles the simple presentation of words to one ear in studies by Bocca *et al.* (1955) and Sinha (1959). Under such conditions, it will be recalled, these investigators found no impairment, but when words were distorted or presented with white noise, a deficit appeared in the contralateral ear even with

unilateral stimulation. It is therefore possible that simultaneous presentation of words to the two ears represents a complication of the same sort and that the deficit is not necessarily attributable to the fact that stimulation was bilateral.

That the contralateral or crossed connections from ear to cortex are stronger or more numerous than the ipsilateral is physiologically well established in the animal literature (Rosenzweig, 1951; Tunturi, 1946). The evidence for a similar organization in man (briefly reviewed earlier) is less direct but still convincing. If we think of these results in terms of what is happening in the intact part of the system, Figure 3 very simply

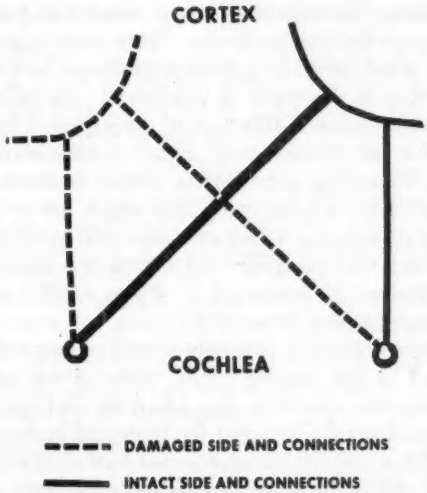

FIGURE 3. Relative strengths of connecting pathways represented by thickness of line.

represents the situation after loss of one temporal lobe. This diagram is meant to represent, not actual pathways, but the relative strengths of the crossed and uncrossed pathways between cochlea and cortex. In the case of a unilateral temporal-lobe excision, one set of connections (from each cochlea to the affected temporal cortex) is relatively non-functional. Remaining are two functional pathways, one from each ear to the intact cortex. This means that, when the ear contralateral to the removal is affected, the pathways ipsilateral to the intact cortex are less efficient than those contralateral to it. This difference is represented by thickness of line. Under some conditions presumably there will be no detectable difference in efficiency between the two remaining pathways, that is, between the two ears. If the stimuli are simple or highly familiar, even

the activity of the weaker pathway will be enough to result in the firing of those central connections corresponding to accurate recognition. If, however, the input is changed in some way such that recognition falls for both ears, the weaker input from the ipsilateral connection (thin line) will cause it to suffer more, possibly through not lasting long enough to permit the recognition of stimuli. Thus single words presented without distortion might be handled by this weaker pathway, but the addition of noise would be expected to affect its efficiency. While studies so far have employed verbal material, this effect would be expected to hold for any type of complex auditory stimulus, non-verbal as well as verbal.

The present study demonstrated a contralateral effect only under conditions of simultaneous presentation, when there was presumably some competition between the two pathways. These data suggest that there is overlap, at some point, between pathways ipsilateral and contralateral to one cortex, and that at this point of overlap the contralateral units predominate over the ipsilateral. This type of arrangement has already been postulated for the cat (Rosenzweig, 1951). Microelectrode studies by Galambos, Rose, Bromiley, and Hughes (1952) indicate that there are units at the level of the medial geniculate which fire to both ipsilateral and contralateral stimulation. Other evidence that overlap takes place at subcortical centres is the occurrence of binaural interaction at the level of the inferior colliculus (Rosenzweig & Wyers, 1955) and the lateral lemniscus (Rosenzweig & Sutton, 1958).

It does not follow, therefore, that only a cortical lesion will produce the asymmetry found in the present study. Even if we assume that the recognition of complex stimuli is dependent on cortical activity, it still follows that any unilateral lesion past the trapezoid body (where crossing of fibres takes place) which interrupts one half of the auditory system should decrease the input from the contralateral ear. That unilateral lesions of the brain-stem auditory system do in fact cause impairment in the recognition of words arriving at the contralateral ear has been recently demonstrated by Jerger and Mier (1960). All that can be said at present about the temporal-lobe excisions is that they too upset the balance in some way.

Summary

An auditory test employing spoken material was given to subjects with epileptic foci in various areas of the brain. This test consisted of the presentation of different numbers to the two ears, either simultaneously in pairs, or in rapid succession. After each group of six numbers, the subject was required to repeat all the numbers he had heard. Damage to the left (dominant) temporal lobe was found to impair over-all performance on this task, irrespective of the ear to which stimuli were presented. In addition, unilateral temporal lobectomy on either side impaired the recognition of material arriving at the ear contralateral to the removal. This effect was independent of damage to the primary auditory receiving area, and it did not occur after frontal

lobectomy. These results suggest that both temporal lobes take part in the elaboration of activity at the auditory receiving area of the same side, and that the left temporal lobe is particularly important in the perception of verbal material, at least in the auditory modality.

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CEREBRAL DOMINANCE AND THE PERCEPTION OF VERBAL STIMULI[1]

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IN A PREVIOUS STUDY (Kimura, 1961) the writer demonstrated that, when different digits are presented simultaneously to the two ears, the following results are obtained:

(1) Unilateral temporal lobectomy impairs the recognition of digits arriving at the ear contralateral to the removal, a finding in agreement with other studies (Jerger & Mier, 1960; Sinha, 1959).

(2) Over-all efficiency, as measured by the total number of digits correctly reported from both ears, is affected by left temporal lobectomy but not by right temporal lobectomy. Both before and after operation patients with lesions of the left temporal lobe are inferior to those with lesions of the right, even when the groups are matched for digit span.

These facts were interpreted to mean that the crossed auditory pathways in man were stronger or more numerous than the uncrossed and that the left temporal lobe played a more important part than the right in the perception of spoken material.

For all groups of subjects studied, regardless of the site of the lesion, the preoperative score was higher for the right ear than for the left. Since the right ear was presumably more strongly connected to the left temporal lobe than was the left ear, this finding suggested that verbal material arriving along this pathway had an advantage in being more reliably transmitted to the hemisphere which was dominant for speech representation. It would then follow that, in subjects with speech represented in the right hemisphere, recognition of verbal material arriving at the left ear should be more efficient. This was the hypothesis investigated in the present study.

METHOD

Subjects

The Ss were 120 patients at the Montreal Neurological Institute with epileptogenic lesions of various parts of the brain. Of these, 107 had speech represented in the left

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[2]Now at the Montreal Neurological Institute.

hemisphere, 13 in the right hemisphere. The 13 subjects in the second group were found to have speech on the right by the technique of injecting sodium amytal into the internal carotid artery of one side, thereby temporarily disrupting the functions of that hemisphere (Wada & Rasmussen, 1960). The right and left sides were injected on different days, with contralateral hemiplegia and hemianopia resulting from each injection. Dysphasia, however, occurred only after injection of the dominant hemisphere.[3]

In the left-dominant group not all subjects were given the sodium amytal test, since it was administered only in doubtful cases. It is possible therefore that one or two subjects are included in this group who actually have speech represented on the right. (Any such cases would tend to minimize differences between groups rather than enhance them.) All left-handers were given the test, however, and the proportion of right-handers with speech on the right is very low in this patient population (Penfield & Roberts, 1959).

Thirteen normal control subjects were also tested. They were all right-handed.

Procedure

The procedure has been described in detail in the previous paper (Kimura, 1961). A dual-channel tape-recorder with stereophonic ear-phones was used for the test. Digits were presented through these ear-phones in groups of six in such a way that half the digits came to the left ear, half to the right. After each group of six numbers, the subject reported everything he had heard, in any order he liked. For the greater part of the test the six numbers were presented as three pairs, that is, two different numbers were presented simultaneously to the two ears, in a manner first introduced by Broadbent (1956). In all cases, different material was presented to each ear. There were 32 groups of six digits, making a total possible score of 96 for each ear.

Results

Table I presents data for five groups of subjects classified according to the origin of their seizures, and for a group of normal control subjects. It demonstrates clearly that the right ear is more efficient than the left regardless of the site of the lesion. This effect was confirmed for the normal group also ($p < .02$, difference t test) but it is somewhat less marked, due perhaps to the higher over-all efficiency. The five groups in Table I, exclusive of normal controls, make up the left-dominant group. Table II compares the relative efficiency of right and left ears for this group and

TABLE I

Preoperative Mean Scores

Group	Left ear	Right ear
Left temporal	76.8	81.5
Right temporal	83.4	88.0
Bitemporal	77.9	80.2
Frontal	82.7	86.4
Subcortical	76.5	85.5
Normal	90.25	92.25

[3]Throughout this paper the term "dominant" will be used to refer to the hemisphere in which speech is represented.

TABLE II

HEMISPHERE DOMINANCE AND MEAN SCORES FOR THE TWO EARS

Locus of speech	*N*	Left ear	Right ear	Right minus left
Left hemisphere	107	76.64	83.01	6.37
Right hemisphere	13	85.00	74.85	−10.15

for the 13 subjects with speech in the right hemisphere. These data indicate that when speech is represented in the left hemisphere, the right ear is more efficient, and when speech is represented in the right hemisphere, the left ear is more efficient.

It also happens that most of the subjects with speech on the left were right-handed, and most of the subjects with speech on the right were left-handed. It therefore seemed important to determine the relation, if any, between handedness and the relative efficiency of the two ears. Accordingly, these two groups were broken down into two more groups on the basis of handedness, and the results are shown in Table III.

TABLE III

SPEECH VERSUS HANDEDNESS
(MEAN SCORES)

Handedness	*N*	Left ear	Right ear
	Left-dominant group		
Right-handed	93	77.03	83.73
Left-handed	10	72.50	77.00
	Right-dominant group		
Right-handed	3	83.67	81.67
Left-handed	9	85.00	71.44

Ambidextrous subjects were omitted from this analysis. It is clear that the ear opposite the dominant hemisphere is more efficient, irrespective of handedness. This is borne out by a statistical analysis of the difference scores between ears. A simple analysis of variance of this difference score for the four groups yields an F ratio of 10.42 ($p < .001$). Subsequent t tests demonstrate a significant difference between the two left-handed groups with speech in opposite hemispheres ($p < .001$) and no difference between the two left-dominant groups with opposite handedness ($.40 < p < .50$). Thus handedness is not a factor in producing these results.

In the group of 13 subjects with speech on the right, nine had widespread damage to the left hemisphere. This was presumably an important influence in producing the development of speech on the right, since the proportion of left-dominant subjects with such damage is very low.

The right hemisphere in these nine cases is both the dominant hemisphere and the intact one, and the superiority of the left ear may be due to either of these factors. That is, the left ear may be more efficient in the right-dominant group because the large lesion in the left hemisphere has depressed performance on the contralateral (right) ear. There are two points against this. First, two of the right-dominant subjects had damage only to the right, the dominant hemisphere, and two more had only minor damage to the left hemisphere. All four of these subjects were more efficient on the left ear. Secondly, seven subjects were selected from the left-dominant group because they had widespread damage to the left hemisphere, and three of the thirteen subjects were dropped from the right-dominant group because they had a high degree of such damage as judged by the presence of weakness or smallness on the right side of the body. These two selected groups were then compared for the relative

TABLE IV

MEAN SCORES OF TWO GROUPS MATCHED FOR LEFT-HEMISPHERE DAMAGE

Locus of speech	*N*	Left ear	Right ear	Right minus left
Left hemisphere	7	70.7	83.0	12.3
Right hemisphere	10	84.4	78.4	−6.0

efficiency of right and left ears (Table IV). Again, it is apparent that the ear opposite the dominant hemisphere is the more efficient despite the presence of severe left-hemisphere damage in both groups ($p < .02$).

DISCUSSION

It appears that when different verbal stimuli are presented to the two ears, those stimuli which arrive at the ear opposite the dominant hemisphere are more efficiently recognized. This is consistent with the view presented in a previous paper that the crossed auditory pathway is the more efficient one, and that the dominant temporal lobe plays an important part in the elaboration of speech sounds. Stimuli arriving at the right cochlea will presumably send more impulses to the left Heschl's gyrus, and hence to the rest of that hemisphere, than to the right hemisphere, and these stimuli will therefore be more reliably identified. Under normal hearing conditions, both cochleas receive the same stimuli, and there is no competition between the pathways from the two ears. This might explain why the greater efficiency of the right ear for speech sounds has so far gone undetected. Another reason for this may be that, in normal subjects, both pathways are very efficient, and only material of a certain level of difficulty will permit the detection of a difference between ears.

If the relation suggested here between the identification of verbal stimuli and the hemisphere at which they arrive is correct, one might expect a similar effect with visually presented verbal material. That is, since material in the right field first excites the left hemisphere, it should perhaps be perceived more accurately than the same material in the left field. Unfortunately verbal material presented visually is subject to some very strong influences in the form of reading habits. These tend under some circumstances to make recognition of alphabetical material better in the left visual field (Bryden, 1960; Heron, 1957). Nevertheless, alphabetical material is recognized more efficiently in the right field under a wider variety of conditions (Bryden, 1958; Forgays, 1953; Heron, 1957; Kimura, 1959; Mishkin & Forgays, 1952).

Forgays' developmental data on the greater accuracy of recognition in the right visual field are in agreement with generally held views on the age range in which speech is taken over by one hemisphere. An interesting point is that, under conditions which make the right field more efficient for verbal material, geometric and nonsense forms are recognized equally well in both fields (Bryden, 1960; Heron, 1957; Terrace, 1959). There is of course the possibility that the increased efficiency of the right field for verbal material is also due to reading experience rather than the dominance of one set of pathways. This suggestion has been made by Mishkin and Forgays, and by Heron, and it derives some support from the finding of Orbach (1952) that experience with Hebrew, which is read in a direction opposite to English, tends to make the left field more efficient. This effect is not entirely achieved, however, and Orbach's data, though incomplete, suggest that the right field may in fact be the prepotent one.

A further test of the hypothesis proposed here might be provided by the presentation of non-verbal material in the same way that digits were presented, since with non-verbal material the right ear should be no more efficient than the left. It would also be of interest to discover at what age the right-ear effect first appears, for such information would have direct relevance for the subject of cerebral dominance. Both these problems are now being investigated.

Summary

Patients with epileptogenic foci in various parts of the brain were given an auditory test in which different verbal material was presented to the two ears. One group of subjects had speech represented in the left hemisphere, the other in the right. Stimuli arriving at the ear contralateral to the dominant hemisphere were more efficiently recognized than stimuli arriving at the ipsilateral ear, that is, in the left-dominant group the right ear was more efficient, and in the right-dominant group the left ear was more efficient. This effect was independent of handedness and of the locus of

epileptic discharge. The results are consistent with earlier suggestions that the crossed auditory pathways are stronger than the uncrossed, and that the dominant temporal lobe is more important than the non-dominant in the perception of spoken material.

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EFFECTS OF DEANOL ON THE INTELLECTUAL PERFORMANCE OF MENTAL DEFECTIVES[1]

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DEANOL (Deaner, dimethylaminoethanol) is a precursor of acetylcholine which is essential to the transmission of impulses in the nervous system. Several reports have suggested that this substance stimulates central nervous activity in animals when large doses are administered over an extended period of time (Konigsmark *et al.*, 1958; Pfeiffer *et al.*, 1957). In addition, it has been claimed that Deanol produces increased mental stimulation and improved learning ability in subjects of average and below average intelligence (Oettinger, 1958; Palmer & Wright, 1958; Pfeiffer & Murphree, 1958). Unfortunately, these behavioural studies have been poorly controlled and the results, consequently, are open to some doubt.

The purpose of the present study was to perform a well-controlled investigation of the intellectual and behavioural response of mental defectives to Deanol as compared with a lactose placebo and a well-known C.N.S. stimulant, d-amphetamine.

PROCEDURE

The *Ss* for this study were residents of the Manitoba School for Mentally Defective Persons located at Portage la Prairie, Manitoba. All had been diagnosed as defectives of the familial or garden-variety (Sarason, 1949). *Ss* having gross defects of speech, hearing, or vision were excluded. From this population a group of 75 *Ss* was randomly selected. They were all given the Wechsler Adult Intelligence Scale (WAIS). One year later they were evenly divided into three groups (A, B, C) matched in terms of chronological age, length of residence in the institution, and I.Q. scores on the full, verbal, and performance scales of the WAIS (see Table I). None of the small differences in matching is statistically significant. During the intervening year, no psychological tests were administered to any of the *Ss*.

Treatment schedules consisted of 50 mg. Deanol, 5.00 mg. d-amphetamine, and a lactose placebo, each given twice daily, at breakfast and at lunch. Precautions were taken to see that the *S* took the pills. All material were in tablets of identical appearance and contained 5.0 mg. of quinine to prevent differentiation on the basis

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TABLE I

DISTRIBUTION OF SUBJECTS BY AGE, YEARS IN INSTITUTION, AND I.Q. ON THE FULL, VERBAL, AND PERFORMANCE SCALES OF THE WAIS.

Group	Mean age yrs.	S.D.	Mean yrs. in institution	Mean I.Q. full scale	S.D.	Mean I.Q. verbal scale	S.D.	Mean I.Q. performance scale	S.D.
A	38.2	11.9	15	58.4	9.5	58.8	8.9	63.7	10.8
B	37.0	14.1	12	59.2	10.0	59.4	8.1	64.7	12.8
C	38.2	11.0	15	60.0	8.8	60.2	8.0	64.9	10.0

of taste. A preliminary check of the tablets indicated that they did taste alike. The treatments were administered over an eight-week period with Group A receiving amphetamine, Group B the placebo, and Group C Deanol. The WAIS was re-administered at the end of the period. In addition to this intelligence test, briefer tests involving coding, Porteus mazes, digit span, number concepts, and word-matching were administered before and at intervals of 4 weeks. The same forms were used at the different test periods. Measures of general behaviour were also obtained prior to the experiment and at weekly intervals by means of the Fergus Falls Behaviour Rating Sheets (Lucero & Meyer, 1951). These were completed by attendants and nurses directly concerned with the care of the *Ss*. All of the other psychological tests, including the first WAIS administerd a year earlier, were given by the same psychometrician. During the experimental period, all *Ss* took part in the regular programme of the training school and none received special treatment other than administration of the tablets and taking the necessary tests.

The nature of the medication received by each of the groups was unknown both to the patients and to all personnel directly involved in the experiment. At the end of the study, tablets remaining from each of the treatment groups were analysed to check against any errors in the distribution of the agents under study.

RESULTS

Table II shows the I.Q. scores obtained by the three groups of subjects on the full, verbal, and performance scales of the WAIS after 8 weeks of treatment with amphetamine, lactose placebo, and Deanol. It can be seen

TABLE II

INTELLECTUAL PERFORMANCE AFTER EIGHT-WEEK PERIOD OF MEDICATION WITH AMPHETAMINE, PLACEBO, AND DEANOL

Scale	Group A—Amphetamine			Group B—Placebo			Group C—Deanol		
	I.Q. before	I.Q. after	Gain	I.Q. before	I.Q. after	Gain	I.Q. before	I.Q. after	Gain
Full scale	58.44	59.12	0.68	59.24	63.64	4.40*	60.00	61.60	1.60**
Verbal scale	58.76	59.12	0.36	59.36	62.48	3.12*	60.24	60.76	0.52
Performance scale	63.68	64.56	0.88	64.68	69.92	5.24*	64.88	67.60	2.72**

*Significant at $p < .01$ **Significant at $p < .05$

that all groups show a gain in I.Q. scores on all three scales of the WAIS. However, the amphetamine group makes a significantly smaller gain than the placebo group on the full ($p < .01$), verbal ($p < .01$), and performance scales ($p < .01$). Similarly the Deanol group makes a significantly smaller gain than the placebo group on the full ($p < .01$) and verbal ($p < .01$) but not on the performance scales ($p > .05$). Finally, amphetamine produces a significantly smaller gain than either Deanol or the placebo on all scales except the verbal scale for Deanol. It would appear, therefore, that Deanol and amphetamine have an adverse or inhibiting effect on intellectual performance as measured by the WAIS.

The results on the monthly tests, namely, coding, mazes, digit span, number concepts, and word-matching showed an improvement of approximately the same magnitude in all three groups. None of these gains was significant. Furthermore, no one treatment produced a significantly greater gain than any other. Similarly, all three groups showed some improvement on the behaviour rating scale but again no one group performed significantly better than any other.

A breakdown of the test data on the basis of age (above and below 40 years of age), length of time in institution, and I.Q. level also failed to reveal any changes which could be attributed to a specific treatment.

Discussion

The results of this study indicate that Deanol does not improve the intellectual performance of mental defectives; in fact, on some of the tests the performance seems to be worse. These results are contrary to those reported by other investigators who have attributed various mental stimulating properties to Deanol. These conclusions, however, are unwarranted since in two studies (Oettinger, 1958; Palmer & Wright, 1958) no control groups were used while in another (Pfeiffer & Murphree, 1958) little or no *objective* appraisals of intellectual performance were made. Our finding that the Deanol group showed a greater gain in WAIS scores than the amphetamine group (but both less than placebo) receives some support in a study by Pfeiffer and Murphree (1958) who reported that "the mental stimulation produced by Deanol . . . was greater than that of amphetamine." We would, however, question their view that this apparent "mental stimulation" was due to the action of the drugs.

Although the present results appear to contradict those obtained on human subjects, they are in line with the animal experiments of Smith and Bevan (1957) who studied the effects of various dosages of Deanol on the T-maze and serial-maze performance of mice and rats. They found that the animals showed either a decrement or no improvement in maze performance. The decrement was associated with higher dosages of Deanol. There were some suggestions, however, that the poorer per-

formance might have resulted from greater emotionality and presence of convulsions in the animals treated with these dosages. It is doubtful whether these two factors could account for the poorer WAIS performance in the present experiment. First, the particular dosage that we used fell in the recommended range for non-toxicity and absence of side-effects (Pfeiffer, 1958). Second, our rating scales revealed no behavioural differences among the treatment groups. Third, if emotional or other behavioural changes were present they should have had an adverse effect on both the WAIS and the series of short intellectual tests. Whatever the explanation of the poorer WAIS performance under Deanol might be, it is clear that this substance does not have a mentally stimulating effect on the intellectual performance of mental defectives.

Summary

Three matched groups of familial mental defectives (25 Ss each) were administered Deanol, d-amphetamine, and a lactose placebo for a period of 8 weeks. Progress of the subjects was evaluated by WAIS testing at the end of two months, by a monthly battery of tests involving coding, mazes, digit span, number concepts, and word-matching, and by weekly behavioural rating scales. On the WAIS the performance of the Deanol and amphetamine groups was significantly worse than that of the placebo group. On the monthly tests and on the behavioural rating scales, all three groups showed some improvement but no one group performed significantly better than any other.

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APPARENT ADAPTATION EFFECTS IN THE ACQUISITION OF A CONDITIONED EMOTIONAL RESPONSE[1]

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THE EXPERIMENTS TO BE DESCRIBED stem from an accidental observation made in the course of preparing a control group relevant to a series of studies on the conditioned emotional response (CER). The CER, first described by Estes and Skinner (1941), consists of a suppression of operant behaviour in the presence of a warning signal (CS) which has preceded shock. Pre-test observations had demonstrated that the CS which we employed (Kamin, 1960; Annau & Kamin, 1961) had no marked effect on the bar-pressing rate of rats stabilized on a variable interval reinforcement schedule. There remained a possibility, however, that the CS—prior to its pairing with the US—might inhibit the bar-pressing of rats which had previously experienced shock in the experimental situation. To test this possibility of a sensitization effect, a few pilot rats were given a number of "free," unsignalled shocks while engaged in their daily bar-pressing sessions. The spacing and intensity of the free shocks were comparable to those employed in our normal CER training procedure. Then, after this prior experience with free shock, the standard CER procedure of CS-US pairings was instituted.

We were primarily concerned with whether bar-pressing would be suppressed by the first CS presentation. This not only failed to occur, but the pilot rats did not suppress even after repeated pairings of CS and US. Thus the prior experience with shock seemed in some way to inhibit the subsequent acquisition of the CER. This seemed to suggest some such notion as adaptation, or habituation, to shock. The phenomenon was in any event deemed worthy of deliberate study, and the following experiments were designed in an attempt to isolate some of the variables controlling the observed effect.

EXPERIMENT I

Subjects and Apparatus

The *Ss* were 26 experimentally naïve male hooded rats from the McMaster colony, about four months of age. The apparatus consisted of standard Grason-Stadler operant conditioning units, with relay, timer, and counter circuits providing for automatic

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programming and recording. The CS was a low-volume white noise from a Grason-Stadler Model 901A Noise Generator, delivered to the experimental chamber through a loudspeaker. The normal sound level of the chamber with exhaust fan operating was 69 db., measured by a General Radio Sound Survey Meter placed in the rat's typical location. The CS increased the measured sound level to 70 db. The US was electric shock from a Grason-Stadler Model E1064GS Shock Generator, with the fixed dial setting calibrated by the manufacturer at .8 ma. employed for all Ss. The current flow across a fixed resistance in series with S was, for the average rat, about .72 ma. The duration of the US was .5 sec. This apparatus has been more fully described in an earlier report (Annau & Kamin, 1961).

Procedure

The Ss had been placed on a 24-hr. feeding rhythm, and had been reduced to approximately 75 percent of *ad lib.* body weight. Preliminary training of all Ss concluded with a minimum of 10 hrs. experience with a 2.5-min. variable interval food reinforcement schedule. The first experimental day of all Ss (day P) presented the CS alone for four 3-min. periods, as a pre-test, during the 2-hr. bar-pressing session.

Control group. The eight Ss assigned to the control group were given, on consecutive days following day P, 20 days of standard CER acquisition training. This consisted of daily 2-hr. bar-pressing sessions, with four CS-US pairings presented during each session. The CS acted for 3 min., terminating simultaneously with delivery of the US. The CS was presented daily 20, 55, 95, and 115 min. after the beginning of the session and was programmed independently of the food reinforcement schedule.

Experimental group. The 14 Ss assigned to the experimental group were given, on consecutive days following day P, 10 days of free shock. The free-shock procedure consisted of daily 2-hr. bar-pressing sessions, with the US alone presented four times during each session. To match the control Ss, the free shocks were given 23, 58, 98, and 118 min. after beginning of the session. Then, immediately following the free-shock experience, 10 consecutive days of standard CER training were given.

The CER is reported in terms of a "suppression ratio" which contrasts S's bar-pressing rate during the 3-min. CS with its rate during the immediately preceding 3 min. The ratio is B/A+B, with B representing number of bar presses during the CS and A number of bar presses during the 3 min. preceding the CS. This ratio has limits of .00 and 1.00, with .00 representing complete cessation of responding during the CS, .50 no effect of the CS, and 1.00 the theoretically possible case in which no responses occur prior to the CS but some do occur during it.

Results

The median suppression ratios of each group are presented in Figure 1, as a function of suppression (CER) training day. The medians were derived by calculating a single suppression ratio (pooling four trials) for each rat for each day. The abscissa of Figure 1, note, is suppression training day, *not* experimental day. Thus, for the experimental group, suppression training days 1–10 are experimental days 11–20.

Figure 1 makes it clear that the experimental animals are severely retarded, throughout their CER training, in the acquisition of suppression.

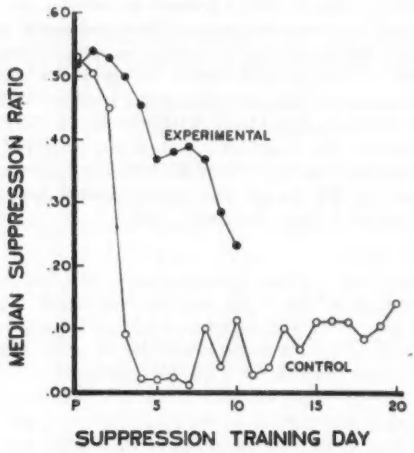

FIGURE 1. Median suppression ratios, Experiment I, as a function of suppression (CER) training day.

To assess the significance of this effect, an over-all supression ratio for suppression training days 1–10 was computed for each rat. The over-all ratio was simply the mean of the rat's 10 daily ratios. The over-all ratios are summarized in Table I. The difference between groups was significant ($p < .002$, Mann-Whitney U test).

TABLE I

OVER-ALL SUPPRESSION RATIOS, DAYS 1–10, EXPERIMENTS I AND II

Measure	Experiment I		Experiment II	
	Experimentals	Controls	Experimentals	Controls
Mean	.38	.17	.28	.10
Median	.40	.16	.29	.09
Range	.22–.56	.07–.29	.13–.36	.05–.17

Pilot observations following formal completion of the experiment indicated that experimental rats showing a severe decrement in the acquisition of suppression speedily acquired complete suppression when intensity of the US was raised substantially. To confirm that the decrement could be counteracted by a more intense US, four new rats were given 10 days of free .72 ma. shock, followed by 10 days of suppression training with a 2.40 ma. US. These very rapidly acquired almost complete suppression, a performance comparable to that of appropriate control rats (Annau & Kamin, 1961).

Discussion

The results of this experiment confirm the initial observation that rats which receive prior experience with shock in the experimental situation subsequently are slow to acquire suppression in the course of standard CER training.

Experiment II

The purpose of this experiment was to repeat the findings of Experiment I, but to employ a slightly more intense US. This change was made in order to make the data comparable with results being obtained in concurrent studies of the CER at the same laboratory.

Subjects and Apparatus

The Ss were 16 rats from the McMaster colony. The apparatus was identical with that employed in Experiment I except for a change in the fixed dial setting of the shock generator. The new setting was calibrated for 1 ma., and provided a current flow, with the average rat, of .85 ma.

Procedure

The basic experimental procedure duplicated that of Experiment I, with 8 Ss in the control and 8 Ss in the experimental groups. The US in Experiment II was .85 ma., during both free-shock and CER training.

Results

The median suppression ratios for each group are presented in Figure 2, as a function of suppression training day. There is again a clear decrement

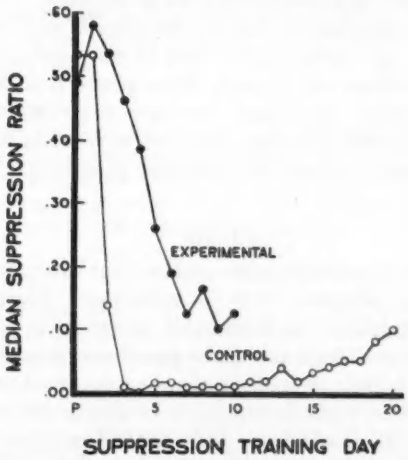

Figure 2. Median suppression ratios, Experiment II, as a function of suppression (CER) training day.

in the acquisition of suppression by the experimental group. The over-all suppression ratios for days 1–10 are summarized in Table I. The difference between groups was again significant ($p < .001$).

The ratios observed in Experiment II seem to be lower, for both groups, than those obtained in Experiment I. This is to be expected in view of the more intense US employed in Experiment II (Annau & Kamin, 1961). The more interesting distinction between experiments concerns the terminal ratios of the two groups *within* each experiment. The first suppression training day of each experimental group, it will be recalled, is the eleventh day of experience with shock. Thus it seems appropriate to compare suppression training days 1–10 of the experimental group with suppression training days 11–20 of the controls. Figures 1 and 2 indicate that, within Experiment I, there is a clear separation between groups for every value of number of days' experience with shock, but that this is not the case within Experiment II. Within Experiment I, the experimentals' ratio on training day 10 is higher ($p < .05$) than the controls' ratio on training day 20. The same comparison in Experiment II yields a non-significant difference in the reverse direction. Thus, from this point of view, the higher US intensity of Experiment II seems to have produced a less persistent decrement.

Figures 1 and 2 also suggest some tendency for ratios to begin an upward drift within 20 days of standard suppression training. The small N in each control group makes it difficult to demonstrate this rigorously, but we can note that, in Experiment I, six of the eight control rats displayed higher ratios for days 16–20 than for days 11–15. Within Experiment II, six of the eight control rats showed this same effect, and one had the same ratio for both sets of days. These proportions do not achieve significance within either experiment, but they do so ($p < .05$) pooling experiments. With several individual rats the increase in ratios near the end of training is quite marked, and smoothly progressive.

Discussion

The results of this experiment again confirm that rats given free shocks in the experimental situation show a subsequent decrement in the acquisition of suppression. The decrement, however, is not permanent. Under some conditions at least, rats given free shocks prior to suppression training ultimately achieve a level of suppression equal to that of rats which have received an equivalent number of shocks preceded by a CS.

The working hypothesis which we have applied to these data assumes that prior experience with the US reduces its capacity to elicit an emotional reaction. The suppression of operant behaviour normally produced by CER training is in theory mediated by an emotional reaction

conditioned to the CS. Thus we assume that suppression training following free shock is being conducted with, in effect, a weak US, incapable of arousing the normally intense emotional reaction.

This line of reasoning suggests that repeated experience with shock—even within standard CER training—should lessen the capacity of the US to elicit an emotional reaction. The pooled results of Experiments I and II, happily, do indicate the ultimate increase in ratios demanded by theory. The ratios observed after continued CER training, it must be noted, are not an uncontaminated index of the rat's emotional state. Thus it is conceivable that the suppression observed after considerable CER training is maintained by habit strength accumulated earlier, and that the US is currently incapable of eliciting an emotional reaction sufficient to produce suppression. Casual observation of rats maintaining complete suppression after prolonged training suggests, in fact, that they are not greatly perturbed by the CS.

Experiment III

With the decrement in acquisition of suppression firmly established, attention was next turned to variables which might exert control over the degree of decrement obtained. The adaptation interpretation suggested that, with intensity of the US during suppression training held constant, the degree of decrement should be a function of the shock intensity employed during free shock experience. The more intense the free shock, the less effective a standard shock intensity should be in producing suppression. This prediction does not arise uniquely from an adaptation interpretation of the decrement, but its confirmation would lend some support to such a view.

Subjects and Apparatus

This experiment involved the training of 24 new rats from the same pool. The study also utilized, as an experimental group, the eight Ss of the experimental group in Experiment II and, as one control group, the eight Ss of Experiment II's control group pooled with eight Ss trained under identical conditions for a separate study. The apparatus was identical with that already described except for changes in shock intensity values.

Procedure

Experimental groups. There were three experimental groups of eight Ss. These Ss, following day P, were given 10 days of free-shock procedure (already described) followed by 10 days of standard suppression training with a .85 ma. US. The groups differed only with respect to the shock intensity employed during the free shock procedure. This was, for different groups, .28, .49, or .85 ma. These intensities have been shown to produce differential degrees of suppression in standard CER training (Annau & Kamin, 1961).

Control groups. Control Group A consisted of 16 rats, each given at least 10 days of standard suppression training immediately following day P. There were no differences in performance between the two squads pooled to form Control Group A.

Control Group B was later added to observe whether the extra bar-pressing practice confounded with free shock training might be responsible for the subsequent decrement in acquisition of suppression. The group consisted of eight Ss which, immediately following day P, were given 10 days of undisturbed bar-pressing sessions, and then 10 days of standard suppression training with a .85 ma. US.

Results

The median suppression ratios for all experimental groups and for Control Group A are presented in Figure 3, as a function of suppression

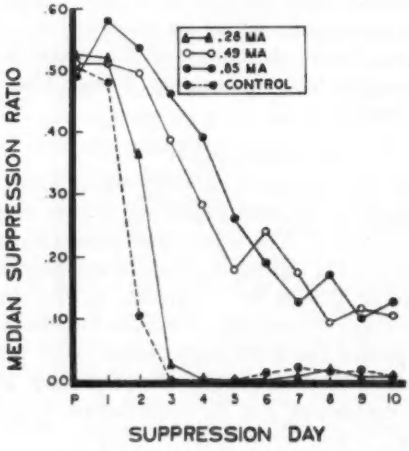

Figure 3. Median suppression ratios, Experiment III, as a function of suppression (CER) training day. Parameter is intensity of free shock.

training day. The figure shows a decrement in the acquisition of suppression for all experimental groups, and indicates the degree of decrement to be an increasing monotonic function of shock intensity during free shock training. The figure also makes clear that, with repeated suppression training trials, differences between experimental groups tend to diminish. Therefore, over-all suppression ratios were computed separately for days 1–5 and days 6–10. These ratios are summarized in Tables II and III. The three experimental groups were tested for the predicted trend with Whitney's bivariate extension of the U test. The trend for over-all ratios, pooling days 1–10, was significant ($p < .05$). The trend

TABLE II

OVER-ALL SUPPRESSION RATIOS, DAYS 1–5, EXPERIMENT III

Measure	Group				
	.28 ma.	.49 ma.	.85 ma.	Control A	Control B
Mean	.18	.35	.43	.15	.12
Median	.20	.37	.44	.14	.11
Range	.12–.21	.13–.55	.26–.52	.08–.25	.06–.17

TABLE III

OVER-ALL SUPPRESSION RATIOS, DAYS 6–10, EXPERIMENT III

Measure	Group				
	.28 ma.	.49 ma.	.85 ma.	Control A	Control B
Mean	.02	.18	.13	.03	.01
Median	.02	.16	.12	.02	.00
Range	.01–.08	.00–.36	.01–.23	.00–.11	.00–.04

for days 1–5 alone was also significant ($p < .01$), but there was no significant trend for days 6–10.

There were no differences between Control Groups A and B, and the day-by-day acquisition curve of Control Group B was virtually superimposed over that presented for Group A.

The decrement obtained with .28 ma. free shock is clearly very transient; from at least Day 3 on these rats are not distinguishable from the controls. The decrement on Day 2, however, is significant. The ratios of the .28 ma. rats differ significantly on this day both from those of Control Group A ($p < .01$) and Control Group B ($p < .002$). When days 6–10 are considered, the ratios of the .49 and .85 ma. groups remain significantly higher than those of all controls and of the .28 ma. group ($p < .002$ in each case).

DISCUSSION

This experiment demonstrates that the observed decremental effect is a monotonic function (within the range of values explored) of the intensity of free shock. This finding is at least consonant with an adaptation interpretation of the decrement.

The data for Control Group B make it clear that the decrement is in no part attributable to the additional practice at bar-pressing provided for those groups which receive free shock. The diminishing differences between groups with repeated suppression-training trials suggests simply that, since suppression training was always with a .85 ma. US, this constant begins to assume control over the behaviour. Thus early differences

between groups, attributable to prior experience, are progressively washed out. There remains, however, a detectable decrement in the .49 and .85 ma. groups even after 10 days of suppression training.

The decrement produced by .28 ma. free shock, transient though it may be, is somewhat surprising. Previous experimentation (Annau & Kamin, 1961) has shown that this US intensity, when employed in our standard CER training procedure, produces no trace of suppression within 10 training days. The same number and spacing of .28 ma. shocks does produce an adaptation decrement. Presumably, the degree of emotional arousal elicited by .28 ma. is not sufficient to interfere with the positively reinforced operant behaviour, while at the same time sufficiently aversive to provide some minimal adaptation.

Experiment IV

This experiment was conducted in an attempt to eliminate a possible alternative interpretation of the decremental effect. The free shock, it will be recalled, is administered while the rat is engaged in a bar-pressing session. Thus it is conceivable that the temporal contiguity of bar-pressing and shock might in some way establish a habit which, during the subsequent CER training, competes with suppression. That is, the rat might acquire response patterns involving bar-pressing and shock very different from those acquired when shock is regularly preceded by a CS. The present experiment provides the free shock experience under conditions which eliminate contiguity between bar pressing and shock.

Subjects and Apparatus

This experiment involved the training of 16 new rats, and also utilized the 8 Ss which comprised the .85 ma. experimental group of Experiment III together with the 16 Ss of Control Group A. There was one apparatus modification. When appropriate, a false wall was inserted into the operant conditioning chamber, which isolated S from the bar. The bar was not visible to S when the false wall was employed.

Procedure

The basic comparison which is the focus of this experiment contrasts the performance of one group which receives free-shock experience with the bar present with that of another group which receives free shock with the bar absent. The Bar Group is the .85 ma. experimental group of Experiment III. The No Bar Group consisted of eight Ss which, following day P, received 10 days of free .85 ma. shock without access to the bar. Thus, of course, no bar-pressing or food reinforcement was possible during the free-shock experience. The free shocks were given at the standard times within the daily 2-hr. session in the chamber. Following free shock, the No Bar Ss received 10 days of standard suppression training.

To observe whether the No Bar procedure in fact produced a decrement, Control Group A (no different in performance from Control Group B) was utilized. There is, however, the additional possibility that 10 days of placement in the operant condition-

ing chamber without access to the bar might in itself affect the subsequent rate of acquisition of suppression. To control against this Control Group C (eight Ss) was added. These Ss, following day P, received 10 days of CS-US pairings (3-min. CS, .85 US) without access to the bar. The Control C Ss were next given 10 days of standard suppression training. Their performance during these days may be appropriately compared with the performance during suppression training days 11–20 of the control Ss of Experiment II. The two groups, prior to the days in question, had received an identical number of CS-US pairings, differing only with respect to whether or not the bar was present during the pairings. With all groups in Experiment IV, US intensity was always .85 ma.

Results

The median suppression ratios of the Bar and No Bar groups, and of Control Group A, are presented in Figure 4 as a function of suppression

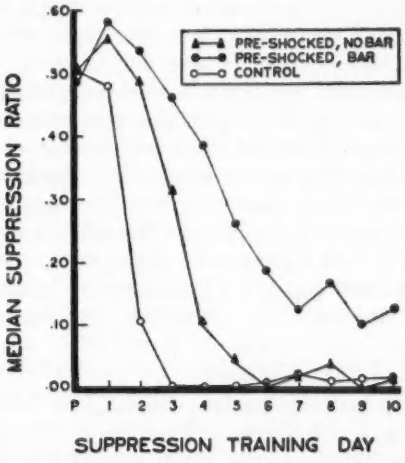

Figure 4. Median suppression ratios, Experiment IV, as a function of suppression (CER) training day.

training day. The figure indicates that both the Bar and No Bar groups show decrements, but Bar rats appear to show a greater decrement. There is, in fact, no detectable difference during the latter half of training between the No Bar and Control groups.

The over-all suppression ratios for days 1–5 and days 6–10 are summarized in Table IV. When days 1–10 pooled are considered, the *U* test indicates all possible differences between groups represented in figure 4 to be significant ($p < .01$, at least). When days 1–5 are considered,

TABLE IV

OVER-ALL SUPPRESSION RATIOS, DAYS 1–5 AND 6–10, EXPERIMENT IV

Measure	Days 1–5			Days 6–10		
	Group			Group		
	Bar	No Bar	Control A	Bar	No Bar	Control A
Mean	.43	.32	.15	.13	.03	.03
Median	.44	.31	.14	.12	.01	.02
Range	.26–.52	.19–.51	.08–.25	.01–.23	.00–.14	.00–.11

again all possible differences are significant ($p < .01$), but for days 6–10 only the differences between Bar and No Bar, and between Bar and Control, are significant ($p < .02$).

The results for Control Group C very closely paralleled those for days 11–20 of the Experiment II control group. The mean over-all ratios of the two groups were, respectively, .06 and .07.

The use of the false wall procedure raised the possibility that the baseline bar-pressing rate, against which the suppression effect is calculated, might be grossly disturbed. Detailed analysis of the baseline responding of all groups in all experiments was undertaken and failed to reveal significant differences between groups. Further, within experimental groups, there were no significant differences between baseline responding on day P and on suppression training days. Within the false wall procedure, S typically began bar-pressing at its normal rate quite promptly on the first day when the wall was no longer present.

DISCUSSION

This experiment demonstrates that the decremental effect cannot be wholly attributed to an interfering habit based on the contiguity of free shock with bar-pressing. There is a significant decrement when free shock is dissociated from bar-pressing behaviour, but this decrement is substantially less than that obtained when free shock is delivered during bar-pressing sessions.

The difference between the Bar and No Bar results, however, need not be interpreted as indicating that the decrements are attributable to two separate mechanisms. Thus, if one conceives of adaptation as being relatively specific to the situation in which free shock is administered, the Bar and No Bar conditions can be reasonably regarded as varying along a stimulus generalization continuum from the experimental situation in which the effects of adaptation are later to be observed. The Bar free shocks, delivered in a situation highly similar to the later testing conditions, would then be expected to produce a more profound decrement

than the No Bar free shocks. This interpretation is clearly more parsimonious than an effort to attribute part of the decrement to adaptation and part to a competing habit, and is consistent with all the available data. The notion that adaptation is specific to the situation in which prior experience with shock occurs is also capable of a more straightforward experimental test. The results of a direct stimulus generalization study, carefully varying the similarity of the free-shock situation to the suppression training situation, would be of obvious interest.

The use of the term "adaptation" in interpreting the decrement calls for some explanation. The long time intervals between shocks, and tests, in the present study make it clear that the mechanism in question is not that involved in the classical adaptation of peripheral sensory receptors, or in "inhibition of reinforcement" (Hull, 1943).

There are many scattered references to shock adaptation in the rat, with particularly relevant studies by Kimble (1955) and by Dinsmoor (1958). Kimble found an increase in the threshold of the jumping reaction to shock during the second half of a series of 160 shocks spaced 30 seconds apart. Dinsmoor reported a decrement in the escape responding of rats which had previously been exposed to 50 minutes of non-terminable shock, and attributed the decrement to competing instrumental responses learned during the pre-exposure to shock. The values for number, spacing, and duration of shocks, however, make these studies non-comparable with the effect reported here. The present data seem to require some notion of a "central" adaptation of emotional reactivity to shock.

Perhaps the data most directly relevant to the present results come from a study by Taylor (1956) of the conditioned eye-blink in human beings. The subjects were exposed to a number of air puffs to the eye immediately prior to the conditioning trials, and the subsequent decrement in conditioning performance was a monotonic function of intensity of the air puff employed during adaptation trials. The interpretation suggested by Taylor is generally very similar to that employed with the present data. The most noteworthy distinctions between her data and the present effect, in addition to the difference in species, are the long time interval between adaptation and conditioning in the present study, plus the current evidence that the adaptation effect may be quite specific to the situation in which prior experience with noxious stimulation is given.

Summary

The effects of prior experience with shock on the subsequent acquisition of an Estes-Skinner conditioned emotional response were investigated in four experiments, employing 82 hooded rats as Ss with standard operant conditioning apparatus. Prior experience with shock produced decrements in the acquisition of suppression in two independent experiments. The degree of decrement was then shown to be a direct

monotonic function of the intensity of the prior shocks, holding shock intensity during CER training constant. The decrement was also shown to be more severe if the prior shocks were delivered in the course of a bar-pressing session than if otherwise. The data were interpreted in terms of a "central" adaptation of emotional reactivity to shock, which is relatively specific to the stimulus situation in which prior shocks are experienced.

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BOOK REVIEWS

The Central Nervous System and Behavior. Edited by MARY BRAZIER. New York: The Josiah Macy Jr. Foundation, 1960. Pp. 475. $7.50.

THIS BOOK IS A VERBATIM REPORT of much that was said during a four-day conference on the central nervous system and behaviour; it was the third conference on this general subject and the special topic on this occasion was maturation. The meetings are supposed to be interdisciplinary, which often turns out to be merely multidisciplinary, but a fair proportion of the book is of interest to psychologists, including some of the non-psychological contributions.

Thus the first contribution, "The Evolution of Man's Brain," by Magoun, Darling, and Prost is a highly readable survey of the fossil and artifactual information about early man and his hominid ancestors. Seventy-four plates accompany this paper, and a nice balance is struck between portraits of early man and early anthropologists.

The next paper concerns biochemical maturation, and was communicated by Roberts with interpolations from the other members. (Before the proceedings got under way the director, Fremont-Smith, urged the participants to interrupt on the slightest pretext, and some of them did, especially during the first papers.) Roberts has measured the quantities of amino-acids in extracts from different brain areas, at different ages in a number of animals, the substance of greatest interest being gamma-amino butyric acid (GABA) which has been shown to have an inhibitory effect on neural transmission. The work is integrated into the interdisciplinary scheme (a little forcedly I thought) by the suggestion that, as GABA increases rapidly during the first few days after hatching in the chick, it might have something to do with imprinting.

An important feature of the policy of the Macy Foundation is to familiarize Western scientists with work being done in Soviet laboratories, and to this end two eminent Russian psychologists, E. N. Sokolov and A. R. Luria, were invited to the conference and made substantial contributions. It seems that the work being done in Russia is not very different from that being done in the West, although the terminology sometimes leads to confusion. Sokolov reported a series of experiments on the "orienting reflex" into which the research done by Sharpless and Jasper on what *they* called the "arousal reaction" could easily have fitted. Sokolov believes that the disappearance of the orienting reflex with repeated stimulation is due to the establishment of a neural "model" of the stimulus ("a chain of neural cells which preserve information about

the intensity, quality, . . . of the stimulus") which acts as a filter to prevent that stimulus from reaching the orienting reflex centres.

Discussion ranged from mention of the fact that complete destruction of the brain-stem reticular formation, if done by suction, does not prevent a waking EEG record to some experiments in which habituation of the orienting reflex in newborn babies was used to measure sensory discrimination, and descriptions of early stages in the histological development of the cortex.

In a subsequent session Hinde describes his work on the habituation of the chaffinch's "mobbing responses" to predators. This raised a number of problems that might have been discussed in the light of Sokolov's presentation, but the discussion got rather off the rails and ended up with a mysteriously irrelevant interlude devoted to the "achievement motive."

Also in the field of animal psychology Harlow gave an account of his well-known experiments on the rearing of baby monkeys with artificial mothers, and elicited a lively discussion. Hess presented his latest results on imprinting Mallard ducklings, and Windle described the behavioural and neural effects of anoxia at delivery in infant monkeys.

Luria's paper, which came next, was a beautiful example of what can be done with the intelligent application of the simplest techniques. By instructing children of various ages (and some with brain damage) to squeeze a rubber bulb, the response being recorded on a kymograph, he was able to follow the development of verbal control of behaviour, revealing a stage at which verbal self-instruction is able to improve performance. The extension of the technique to adult patients with frontal and parietal lobe lesions also give interesting results.

The last session was a more philosophical discussion of language, in which Bridger tried to draw a sharp dichotomy between animals and man. He ran into some opposition to this, especially from the animal psychologists, but it was interesting to see that the Russians, with the authority of Pavlov behind them, were among the most eager to have the dignity and uniqueness of man upheld.

In summary, I would recommend anyone who is at all involved in any of the topics mentioned to read through the appropriate sections. It is impossible to convey here the mixture of snippets of valuable information, ideas, and inanities that result from the supercharged discussions among these experts. It is certainly not a book for the dabbler who knows little about the material to start with, but it is a good way for the more sophisticated to keep in touch with his field.

P. M. MILNER

McGill University

Markov Learning Models for Multiperson Interactions. By PATRICK SUPPES & RICHARD C. ATKINSON. Stanford, Calif.: Stanford University Press, 1960. Pp. xii, 296. $8.25.

IN THIS MONOGRAPH, Suppes and Atkinson set out to extend Estes' stochastic model of learning into the realm of social psychology. Such a venture can serve two ends: it can contribute to the development of a mathematical theory of behaviour, and it can show the merits of using a mathematical approach to problems in social psychology. On the first count, Suppes and Atkinson have succeeded in making a number of significant advances in stimulus-sampling theory. They are not, however, as successful in demonstrating the fruitfulness of their approach to multiperson interactions.

The simplest of the mathematical models presented, a one-element model, is far too crude to fit experimental data with any precision: it is useful as an illustration of the procedure and as an approximate test of the fit of the more complex models. An alternative multi-element model provides a more satisfactory fit to data, but requires such a staggering amount of computation that it is not likely to be useful in practice. The most promising alternative seems to be the generalized conditioning model, a flexible single-element model discussed in detail for the first time in this book.

Clearly, one of the theses of this book is that interpersonal interactions can be treated in terms of stimulus-sampling theory. In order to test this notion, the various models are applied to data from a number of experiments, mostly simple two-person games in which the payoff depends on the responses of both players. The players are never permitted to communicate with one another verbally, although in some experiments one player is informed of the other's responses by a signal light. It is rather difficult to see the "multiperson interaction" aspect of such experiments: they seem merely to provide a novel way of generating rather complex reinforcement schedules. Applicability to experimental situations like these is not likely to convince many people that a similar model will fit more complex social behaviour.

The experimental results indicate that the models can adequately predict asymptotic response probabilities. They are less successful in making more detailed predictions, and the authors are often content if the fit is not ridiculously inadequate. One of the constantly recurring problems is that the maximum-likelihood estimates of the stimulus-sampling parameters, obtained from the transition frequencies, predict learning curves which reach asymptote much too rapidly. It is clear that stimulus-sampling theory provides only a rough fit to the data and that further

assumptions and more complex models are required to make more adequate predictions. Suppes and Atkinson are well aware of these difficulties and advance a number of suggestions for strengthening their models.

For the devotee of mathematical learning theory, this book contains many new ideas which will be of interest. Its primary value for others lies not in the actual theory, which is still in the formative stage, but in the intimate view it gives of the slow process involved in the development of a quantitative theory of behaviour.

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Behavior Genetics. By JOHN L. FULLER & W. ROBERT THOMPSON. New York: John Wiley and Sons, Inc., 1960. Pp. ix, 396. $8.95.

IN RECENT YEARS the volume of research concerned with the genetic determinants of behaviour has increased tremendously. Consequently, a comprehensive review of this material should be most welcome, especially if it succeeds in putting into perspective the different research approaches that have been used. The textbook by Fuller and Thompson admirably fulfils both needs. Written for the advanced undergraduate and graduate student, it should serve equally well as a reference for scientists immediately concerned with behaviour genetics and as a source for any psychologist or biologist who is interested in keeping abreast of the field.

The book is divided into three sections. The first four chapters are devoted to background material including principles of genetics, and experimental and statistical methods. Controversial issues are mentioned in the first chapter but superficially. Thus, while one may agree with the authors' orientation, it seems unlikely that the student will acquire any real understanding from the text alone. Unfortunately, only a few of the many relevant papers are cited. The methods sections, almost inevitably in view of the broad coverage, tend toward the "cook-book." Still, they should provide useful background for understanding the experimental papers reviewed.

The second section contains an extensive and well-organized review of the literature (through 1958) on the genetic contributions to intraspecific differences in behaviour. Chapters are on sensory and perceptual processes, response processes, intellectual abilities, personality and temperament, and mental disorders. By far the greatest number of the more than 800 references are from this section. The main emphasis is on the genetic mechanisms of inheritance, but physiological mediators are discussed in some detail whenever the information is available. The many studies

which serve only to demonstrate statistically significant differences in behaviour of different strains are not accorded much attention.

Since the dependent variables discussed cover very nearly the entire field of psychology, it is not surprising that studies are presented with relatively little criticism. For the most part, the original authors' statements concerning the behavioural manipulations and measures are accepted without comment. This is especially noticed in sections dealing with human behaviour. However, a more critical attitude is taken toward the genetic aspects of the papers cited.

The last section, one chapter, is devoted to a discussion of population and physiological genetics with examples drawn from human and animal research. Nothing new in the way of theory is offered, but existing models for inheritance and for the physiological links between genes and behaviour are described and evaluated.

While at no time profound, this book constitutes a careful and well-presented synthesis of literature and thinking in an important area of research.

R. G. RABEDEAU

Queen's University

An Introduction to the Principles of Psychology. By B. R. BUGELSKI. New York: Rinehart & Co., Inc. Pp. xvii, 571. $6.00.

WITH THE PLETHORA OF INTRODUCTORY TEXTS AVAILABLE, one approaches yet another one with the hope that it will be distinctive and preferable to the others in order to justify its appearance. Professor B. R. Bugelski, a well-known learning psychologist and author of two previous books, did fulfil this reviewer's hopes in this regard. The book is the work of a scholar-scientist and he is to be commended for this worthwhile publication.

While the author's aims are not radically different from those of certain other writers, the end result is a fresh, distinctive, and sophisticated treatment of the fundamentals of psychology from a learning orientation. The first part of the book, "The Modifiable Aspects of Man," consists of eight chapters dealing with such topics as the definition of psychology, psychology as a science, the problem of nature and nurture, sensory processes, the nervous system, psychometrics, the nature of learning, and the transfer of training. In a sense, the first part carries the basic argument of the book and acts as a golden thread connecting the remaining chapters. The second part, "The Integrated Aspects of Man," contains eight chapters which concern themselves with the problem of classifying behaviour, cognitive functions, conative functions, affective processes, con-

flict and adjustment, the nature of personality, social interaction, and the means whereby human nature is controlled and modified.

The distinctive and scholarly features of the text are many. Rather than writing a series of discrete and often contradictory chapters, Professor Bugelski deserves credit for writing a text which provides an integrated and theoretical treatment of psychological phenomena in terms of learning principles and mediational processes. The theoretical position has strong overtones of the late Edwin R. Guthrie and the behavioural interpretation of learning, set, perception, and motivation is practically indistinguishable from that of Guthrie. Unlike Guthrie, however, the author feels that it is necessary to construct a conceptual nervous system, which leans on Hebb, in order fully to explain behaviour. The systematic position is introduced very early in the book and it is used effectively thereafter. The author obviously believes that a psychological theory is not only a scientific tool but also a teaching device. Probably as a consequence of adopting a systematic position, Dr. Bugelski did not feel compelled to provide the reader with a psychological mausoleum of venerable and hoary facts. With non-essentials stripped away, he brings into focus the principles of psychology and shows how they may be used to explain behavioural phenomena, including consciousness, imagery, and meaning.

The author assumes that university freshmen can read and want to be challenged intellectually. Many students will find this book difficult, as the presentation is often abstract and deals with problems and controversies which are of primary theoretical concern to psychologists.

While the reviewer is impressed with the book, various doubts and criticisms may be raised about it. Psychologists with a genetic orientation will feel that the rôle of learning is overplayed. Those with strong allegiance to Skinner, Hull, Tolman, or Mowrer may be prevented from accepting Bugelski's systematic interpretation of learning, motivation, and the cognitive processes. Psychoanalytically and clinically-oriented psychologists may think that his interpretation of analytic thinking and the general deprecation of post-diction studies are those of a castrating experimentalist. His schematic treatment of a limited number of experiments may not sufficiently convey to the beginning student the vigorous nature of psychology as an investigative science.

To this reviewer, the chapter on psychometrics is most disappointing because it fails to reflect contemporary thinking in the field of tests and measurement and is not in keeping with the level of sophistication shown throughout the rest of the book. His standards of stringency for tests are unrealistic and outmoded. The author does not seem to be aware that a test with a validity as low as .30, and a reliability only somewhat higher, may be a worthwhile test for certain predictive situations. His discussion

on the important topic of the constancy of the I.Q. is weak. It is unfortunate that he did not make use of the wealth of empirical data on this problem, such as the findings of Bayley, who retested children from the first month of life to 18 years, or the data of Bradway, Thompson, and Cravens who retested individuals after 25 years with the Stanford-Binet. These criticisms highlight only a few of the weaknesses of this chapter.

While this book may not meet the needs of all instructors, the reviewer considers it to be one of the better texts on the market and believes that it can be recommended to all who are looking for a solid and systematic treatment of psychology.

DOUGLAS T. KENNY

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Reflexes to Intelligence: A Reader in Clinical Psychology. Edited by SAMUEL J. BECK AND HERMAN B. MOLISH. Glencoe, Ill.: Free Press, 1959. Pp. xvi + 669.

THIS IS A COLLECTION OF "READINGS" in clinical psychology. It contains more than 60 articles or excerpts, reprinted in whole or in part, arranged in seven sections for each of which the editors have supplied an explanatory introduction and a concluding list of auxiliary readings.

For anyone required to teach clinical psychology under conditions where library resources are limited, this volume should prove to be an invaluable supplementary reading aid. The editors are well-known clinical psychologists of wide experience and mature judgment. They have collected and placed within the covers of a single book a large sample of the authoritative and influential writing on this complex subject.

It would be too much to expect that anyone could make such a selection without arousing specific objections to the inclusion of certain items and the omission of others. For example, the perfunctory four-page introductory bow to "Clinical Wisdom in Former Times," with its few very short fragments to represent Homeric, Biblical, and Shakespearean clinical wisdom, surely does less than justice to these potential sources. On the other hand, part one on "Sources and Foundations" serves with the voices of Darwin, Ebbinghaus, Titchener, James, Watson, Morgan, and Dewey to locate the roots of clinical psychology in the common soil of our basic discipline. Properly counterbalancing this beginning is a chorus led by Sigmund Freud.

The section on mental measurement seems somewhat slighted with only Binet, Terman, Goodenough, and Haggard to speak for its history. An odd note is struck by Molish's own final article in the section on projective signs of organic brain damage. It is a very thorough and detailed review

of the literature on this topic, four times the length of the average selection in the book, and winds up with the conclusion that "a great deal of work remains to be done."

If mental measurement is slighted, orthopsychiatry is not, since "Disciplines in Interaction" and "Humans in their Social Context" constitute nearly half of the volume. The final section is devoted to "theorists" and will, for many users, be the most valuable part of the book bringing together as it does contrasting but well-chosen excerpts from Holt, Lewin, Rapaport, Mowrer, Allport, Rorschach, Bruner, Postman, and Brunswick.

ROGER MYERS

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Development of the Perceptual World. By CHARLES M. SOLLEY & GARDNER MURPHY. New York: Basic Books, Inc., 1960. Pp. xiv, 353. $6.50.

NOT SO LONG AGO it was relatively easy to embarrass almost any student of perception or learning by asking him to give a theoretical account of perceptual learning. Even though the data related to both long-range and experimentally-produced changes in perception have been accumulating steadily, theoretical attempts at integrating and explaining these data appear to have been uninteresting to students of learning and often of only marginal concern to thinkers in the field of perception.

Now the situation seems to be changing. Not that there has been any great deal of progress in empirical or theoretical development. It is just that the young field of perceptual learning has been given official recognition as a full-fledged problem area in psychology. It thus seems to be acquiring respectability that attracts and compels responsible action. Last year for the first time the *Annual Review of Psychology* included a chapter on "Perceptual Learning." And now we have on hand the first book devoted entirely to a broad and diverse survey of what is known in the field, together with a systematic framework for the findings.

For this reason alone—that it is the first of its kind—Solley and Murphy's interesting book represents an important contribution to the psychological literature. In bringing together a large array of relevant problems, facts, and tentative conclusions, and placing them in the familiar perspective of concepts of learning, it may well give a long needed strong impetus to the conceptual development of the field.

The book is organized into two major sections. In the first the authors consider how various well-known variables and concepts, such as practice, reinforcement, motivation, affect, and punishment apply to perceptual learning. They also present what they call their own point of view as to changes in perception attributable to learning. This point of view

is based on a closely drawn parallel between an instrumental act and a perceptual act. As the former operates on the physical environment and transforms it, so the latter has the effect of restructuring the perceived environment. And as the former can be analysed into smaller molar components, which can be considered separately, so the latter can be thought of as consisting of various stages which can be and should be examined one by one. The stages sound straightforward and familiar enough: expectancy, attention, reception of the stimulus, trial-and-check together with autonomic and proprioceptive arousal, and finally, the product of the perceptual process—the percept.

In the second major section the effects of the "successive applications of the operations of a learning paradigm" on these molar events are discussed by referring to a wide, though somewhat biased selection of published studies, and are evaluated in terms of well-known principles of learning. It is in this part of the book that the authors generate some of their more interesting hunches and heuristic insights.

Readers' reactions to the book are probably going to be as varied as the authors predict: some will agree with everything they say, some will agree with certain points and not with others, some will reject the whole approach. Among the many factors that determine such reactions probably the more important are tolerance for ambiguity and spirit for adventure. For example, an intolerant reader is likely to take a dim view of the authors' peculiar understanding of necessary and sufficient conditions, and too liberal a treatment of experimental controls when interpreting data. Very few readers will probably agree with the authors that contiguity, motivation, and reinforcement are necessary conditions for learning, and that we know little about sufficient conditions. It is difficult to take seriously the view that for perception to be inferred a response must be observed which cannot be made equally well in absence of the stimulus. (p. 17) Surely more than this is involved, but the insistence on converging operations is bound to be futile unless the ground rules are more clearly specified. Thus the insistence on the stimulus being both necessary and sufficient for a response in order that perception may be inferred, while logically impeccable, suffers from the limitation that necessary conditions are never completely known. On the one hand this means that perception can never be defined, on the other it also means that there are no logical grounds for referring to most experiments discussed in the book as experiments in perception. As to the controls, it seems, for instance, that there are no logical grounds for concluding on the basis of the experiments considered in chapter 10 that what is altered during practice is sensory reception, as the authors maintain, rather than some other aspect of the p[illegible]rceptual process.

At the same time a more tolerant and hence more adventurous reader will probably find the book refreshing and stimulating. He will approve, or at least keep an open mind about, the proposition that veridical perception is achieved through negative reinforcement of autistic perceptions (p. 78) and understand the rationale of studying perceptual development in terms of experiments in which subjects learn to perceive nonveridically.

Thus, if one believes that it is better to be bold and run the risk of being wrong in one's attempts to crack the mysteries of the universe, than to insist on a methodologically "pure" and theoretically "sound," but often unimaginative and sterile, approach to the unknown, he will be pleased with Solley and Murphy's accomplishment. Even if he insists on purity, however, he will find perusing this book both profitable and thought provoking.

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